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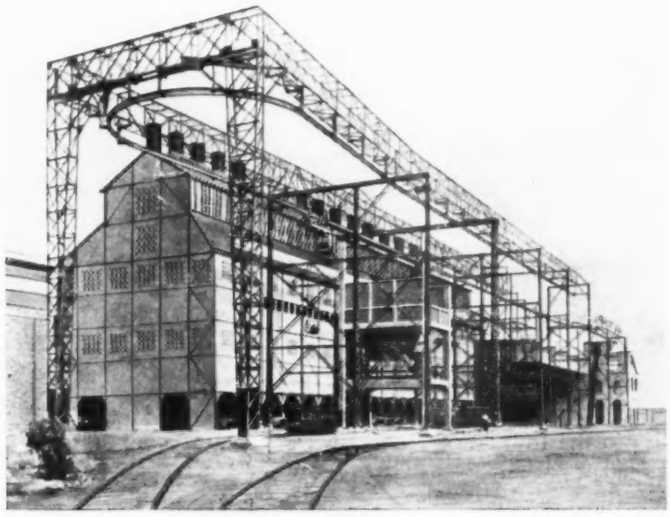

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Belgian-American Coke Ovens Corporation

THE BELGIAN-AMERICAN COKE OVENS CORPORATION has been recently organized as a United States Company. It has acquired all the patents and rights in the United States and Canada of the Franco-Belgian Coke Ovens Corporation of Brussels (Belgium) for the construction of the several types of Piette System By-product Coke Ovens and Recovery Plants.—

More than 1500 Piette ovens have been built and are in operation in several countries in Europe. Previous to the organization of the Belgian American Coke Ovens Corporation, a demonstration battery of Piette ovens has been erected at the coke station of the Laclede Gas Light Co., St. Louis, Mo., and is being successfully operated by the latter company after very minute tests and measurements of yields were made during thirty consecutive days.

Inspection of said demonstration battery is invited and complete information on the remarkable yields shown by same will be supplied on application.

The main characteristics of the Piette Ovens are:

The ovens are of the horizontal type with vertical flues, transverse regenerators and reversing arrangement. The construction is the simplest there is and the shape bricks are less numerous than anywhere else. The maximum of stability is attained by building the ovens proper on an absolutely rigid monolithic bloc.

The method of feeding the heating gas by regulation tuyeres enables a distribution at every point of the oven walls of the exact amount of gas required for a perfect coking.

The regulation sections for the control of the gaseous currents are calculated before construction and exclude the need of numerous dampers and sliding bricks.

The simplicity of the regulation has been exceeded nowhere.

The checkerworks of the regenerators situated in the longitudinal galleries are crossed transversely by either the waste gases or the air, securing the equalization of the temperature in the whole battery without preventing the isolation of any one oven in case of stoppage.

The arrangement of the galleries in the foundations realizes a superior cooling of the waste gas by the incoming combustion air besides reducing the loss of heat by radiation.

The BELGIAN-AMERICAN COKE OVENS CORPORATION is prepared to contract for the building of Piette By-Product Recovery Coke Ovens, with or without recovery of heat, also for plants for condensation and distillation of tar, production of sulphate of ammonia or concentrated liquor, recovery of benzol and carbolic acid, manufacturing of pure products: volatile alkali, benzene, toluene, xylene, naphthalene, phenol.

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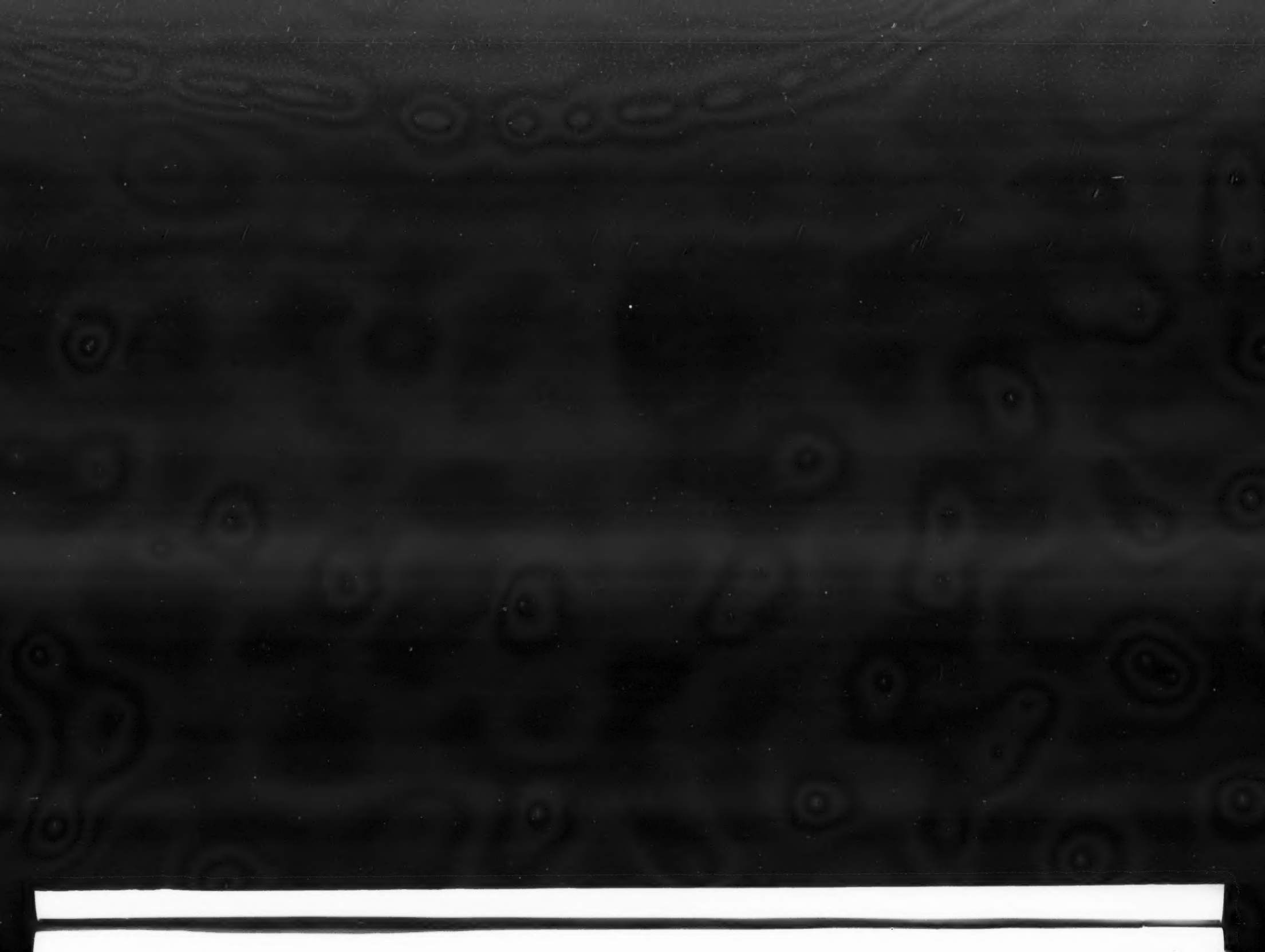

American Gas Journal
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Risks in Handling and Storing Coal, Oil and By-Products

The Subject Is Treated from a Fire Standpoint

By C. E. PAIGE
Manager, Worcester Gas Light Company, Worcester, Mass.

The first thought when coal-pile fires are mentioned, is spontaneous combustion. Some coals, on inspection, indicate that they can be stored under any condition without self-ignition. Others look as if they might fire easily. The great difficulty comes with coals which do not appear dangerous until the fire actually starts.

Anthracite coal gives no trouble in storage; gas coal of reasonably good quality rarely gets afire. The great risks are in bituminous and semi-bituminous coals of poorer quality. Market and other conditions make it necessary at times to handle coals that may take fire. Usually the fire comes as a surprise. It is well, therefore, to take precautions in all cases, where there is the slightest question as to the origin or quality of the coal

We assume that the cause of spontaneous combustion is too well understood to require discussion.

When a fire occurs in a coal pile, the dangers are of two kinds—loss in value of coal, and the hazards of workmen dealing with the problem.

Fire risk may be reduced if precautionary facilities are provided and used. There is no danger of spontaneous combustion if suspected coal is stored under water. Such storage is not often practicable.

Coal is less likely to fire if stored under cover of a shed with air-tight sides and a good flooring.

The risk is reduced if coal can be unloaded without breakage, which often exposes new surfaces to the air and permits heating.

Some years ago we had a pile of steam coal, about 5,000 tons, unloaded from a wooden trestle twenty-two feet high. The coal had been boomed over from the track by a locomotive crane grab bucket. The pile was about twenty feet deep. It began to heat. We opened the pile but, owing to lack of time and space, we were unable to do the work thoroughly. Our effort reduced the combustion but did not stop it. We began using water from a fire hydrant. When used in small quantities for local burning it seemed to extinguish the fire in one spot, but a little later all the coal around this spot began heating rapidly. Then we began soaking the pile, day and night. We finally got the coal so wet that the heating stopped. We do not believe that this treatment would be effective for dealing with fire in larger piles, nor with all kinds of coal. When there was no more indication of heat, we shut off the water. In a few days the pile began to heat again. We put on the water again. The menace was not eliminated until the coal was used in the boilers.

A year ago we in New England were scrambling for an adequate gas coal supply. We were paying all kinds of prices for any kind of coal. Buying from many sources and receiving all coal into one shed made separate storage out of the question.

Our shed is built with reinforced concrete plaster sides, tile roof and an oak floor. The coal is dumped from a trestle eighteen feet high and is reclaimed by an overhead crane. Our pile showed signs of heating. No particular precautions had been taken because we had never experienced any trouble before with gas coal.

The crane operator saw little spurts of smoke and steam issuing here and there from the pile. There was also noticeable the acrid smell due to slow combustion.

We began using up the coal from this part of the pile, and handling over the stock. The fire was all in one end of the shed. In spite of rehandling, the zone of combustion began spreading. To prevent the spread to the main pile, we dug a deep trench through the middle of the shed, practically making two piles. We had already demonstrated that while the better coal did not show signs of heating by itself, it began to heat if in contact with coal of poorer quality.

This paper, which was delivered at the tenth annual congress of the National Safety Council, contains much valuable information for the gas industry. We are publishing it in place of the usual article on safety which ordinarily appears in this issue.—Editor.

We then opened the sides of the shed and moved a large part of the suspected coal out, piling it in heaps not more than four or five feet deep. In this way, we isolated certain parts of the pile which were very active, and quenched the fire with water.

Here again we found that the real cure was getting rid of the coal.

One feature of dealing with this fire which made our work so difficult was the problem of shed ventilation. The fumes from the fire, with the steam vapor, made a condition which was most uncomfortable. One could not see more than a few feet and the foul air affected the men in some cases. In fact, we had to cut holes in the shed to provide additional ventilation. In spite of this, the men had to wear masks at certain times.

From these experiences, we learn that there are no known guarantees against this trouble. We recognize, though, that the risk may be mitigated by observing a few simple rules, when it is possible to do so:

Suggestions on Storing Coal

With full appreciation of the fact that any or all of the following precautions may prove impracticable or unreasonably expensive under certain conditions, they are offered as advisable for safety in storing bituminous coal:

1. Do not pile over twelve feet deep, nor so that any point in the interior of a pile will be over ten feet from an air-cooled surface.
2. If possible, store only screened lump coal.
3. Keep out dust as much as possible. To this end reduce handling to a minimum.
4. Pile so that lump and fine are distributed as evenly as possible; not, as is often done, allowing lumps to roll down from the peak and form air passages at the bottom of the pile.
5. Rehandle and screen after two months, if practicable.
6. Do not store near external sources of heat, even though the heat transmitted be moderate.
7. Allow six weeks' "seasoning" after mining and before storing.
8. Avoid alternate wetting and drying.
9. Avoid admission of air to interior of pile through interstices around foreign objects, such as timbers or irregular brickwork, or through porous bottoms, such as coarse cinders.
10. Do not try to ventilate by pipes, or more harm may often be done than good.

Oil

Gas oil is a raw material which should offer very little menace as a fire hazard, providing the simplest precautions are observed.

I quote from a well-known authority on the subject:

"The storage of gas oil in connection with gas manufacturing plants should be in steel tanks with tight steel roofs. Underground concrete tanks are suitable and safe, but the expense is usually prohibitive, unless real estate is very limited. As gas manufacturing plants are permanent institutions, steel storage tanks used for gas oil should be of a heavier design than is common in ordinary oil-field practice. I would recommend that they be designed not less than a safety factor of three when fully loaded with water. The roofs should also be heavier than usual oil-field practice, and I would recommend that the roof plates be not less than three-sixteenths of an inch thick. The lighter roofs usually furnished on standard tanks are subject not only to quicker corrosion, but also will not remain tight in service. All fittings on the tanks, such as nozzles for connecting pipe lines, should be of cast steel. There should be swinging joists in all the pipe lines that connect to the sides of the tank, and double valves are a wise provision. There should not be any bottom connections.

"The vent from the tank should be properly screened and frequently inspected so as to insure that the screen is neither clogged nor corroded.

Storage Tanks Should Be Isolated

"The gas-oil storage tanks should be as remote from operating buildings as is possible on the plant sites involved, and should in any event be surrounded by emergency dikes which would impound the contents of the tank in event of its collapse. Where the real estate is available, earthen dikes six to eight feet high, forming a basin which will hold 50 per cent more than the capacity of the proposed tank, are the cheapest and best protection. Where the real estate is limited, concrete dikes, or even steel dikes, may be used, but I personally am not inclined to favor the steel dikes as they are likely to be destroyed by the heat from the burning oil. I consider that the diameter of the dike wall, if high and made of either steel or concrete, should be at least fifty feet greater than the diameter of the enclosed storage tank. Between the shells of adjacent tanks there should be a space not less than the National Board of Fire Underwriters requires for fuel-oil storage.

"The tank should be thoroughly grounded and all openings except the screen vent be made perfectly tight, and with these precautions there is little likelihood of ignition by lightning, even if the tank is struck.

"The tanks should be equipped with a so-called safety steam line, which is merely a pipe normally empty connected to the general steam supply of the plant and having two or three, or more, inlet connections into the tank near the top angle. The valve admitting steam to this line should be not less than fifty feet away from the tank, and preferably more. If the tank gets on fire and the roof is not blown off, the admission of steam through this safety line will put out the fire.

"The only way to put out a fire in a gas-oil tank, if the roof has blown off, is by the application of Foamite solution. Foamite solution, if properly installed and operated, is practically absolute protection against any extensive oil fire, but in the ordinary gas plant the expense involved is usually not justified because the hazard is small and the rates on insurance are not greatly reduced by installation of the Foamite system.

"It is very useful to have the piping and pumping arrangements so that in the event of a fire occurring in one tank the contents can be rapidly pumped out into another tank, reducing the loss.

High-Pressure Hydrant Needed

"There should, of course, be ample high-pressure

(*Continued on page* 326.)

Gas Holder Capacity vs. Generating Capacity*

The Question Discussed from an Oil-Gas Viewpoint

By J. M. DICKEY
Engineer Gas Generation, S. F. Division, Pacific Gas & Electric Company

The writer will consider the subject strictly from an oil-gas point of view and it will also be confined to the generating man's ideas.

To-day, gas is used for lighting, heating and cooking in the home as well as for almost every conceivable purpose in the industrial world. All send-out curves will, therefore, show two distinct peaks, morning and evening, and others will even show a third peak, not so pronounced, at the noon hour. How simple it would be from a generating engineer's point of view if the send-out curve were a straight line for the whole twenty-four hours; no peaks and no off hours to consider.

Before proceeding to a discussion of what would seem to be the proper relation between storage and generating capacity, it will be interesting to note the actual conditions under which certain of the plants on the Pacific Coast operated during last winter's peak. One plant had a maximum day's send-out of over 52,000,000, peak hour 4,300,000, with a storage capacity of 15,000,000, only 28 per cent. The generating capacity of this plant was only 51 per cent of this day's send-out, the balance made up from natural gas. Another plant delivered 14,450,000 with a peak hour of nearly 1,500,000, storage capacity 22 per cent, or 3,200,000. This plant depends on artificial gas entirely with a generating capacity of 25,000,000. Incidentally, both these plants are making substantial additions to both storage and generation this year. These are two extreme cases but both managed to handle the load safely with very low storage capacity. No oil gas plant of any size on the Pacific Coast had storage last winter equal to 50 per cent of the maximum day's output. The average for five of the largest plants was 36 per cent, ranging from 22 per cent the lowest, to 48 per cent, the highest. The average available generating capacity of four of these plants, which depend entirely on manufactured gas, was 132 per cent of the maximum day, ranging from 87 per cent to 173 per cent. The one with only 87 per cent is adding to its generators this year.

Every plant has its own individual problems to meet and every generating engineer has his own ideas as to how they should be met Doubtless, no two will agree exactly but this paper is intended to develop something from which we can work.

Dealing with Peak Conditions Only

Starting with a theoretical plant, we will deal with peak conditions only, as every plant is constructed to take care of the maximum load. The send-out figures, percentages I mean, will not apply to every individual case but are averages derived from reports of last winter's peak conditions in a dozen different plants.

This theoretical plant will have a total generating capacity of 24,000,000 cu. ft. consisting of six units of 4,000,000 each four operating and two standing by. The maximum day's send-out will be 16,000,000, and the maximum hour 1,600,000. Storage capacity 11,000,000, or slightly less than 70 per cent of the maximum day. It is understood that there is ample scrubbing capacity, purifiers, oil pumps, blowers and other auxiliaries to take care of this peak load. Blowers, pumps and exhausters should be duplicated, some electrically driven and some with steam and gas engines. Of course, there should be a sufficient number of scrubbers and purifiers to allow for scrubbers steaming and purifiers reviving.

During the twelve-hour period from 7 A. M. to 7 P. M., 11,200,000 cu. ft. of the 16,000,000 maximum day, or 70 per cent, will go out, leaving a balance of 4,800,000 to be sent out during the night. At 7 A. M. the storage holders are full and four generators operating, making 668,000 cu. ft. per hour. The average hourly send-out up to 6 P. M. will be 933,000; therefore, during the eleven hours nearly 3,000,000 will be drawn from storage, leaving 8,000,000 on hand at the beginning of the peak hour.

In some cities the peak hour does not necessarily come in the evening, it may come sometime during the forenoon. This is a decided advantage because the earlier in the day it comes the greater amount there is in storage to meet any unusual demand. However, for this particular plant it is supposed to come between 6 and 7 in the evening.

The peak-hour send-out, it will be recalled, is to be 1,600,000, and the plant stands ready to meet it with 500 per cent of that amount on hand. This comparatively large amount on hand at this time seems to me to be an important factor in the plant operation. If anything is going to happen to the mechanical apparatus, it is more liable to occur during the peak hour because everything is running at or near maximum speed and capacity. Furthermore, something psychological; the operating crew are keyed up to the highest pitch and if some one of them, unknown to you and perhaps himself, has a weak link in the chain of his make-up, he may "go to pieces" just at the critical moment and do the wrong thing. But, with 500 per cent of the peak-hour demand in storage, there is little to worry the man in charge. He knows that, if necessary, all of the generators could be shut down entirely until after midnight and still the plant would be out of danger in the morning. It is presumed that in a plant of this size there would be at least two storage holders; should anything happen to one of them it could be by-passed and the plant operated in the other alone until repairs were made.

Four generator units are operating continuously and two are standing by. In a plant with 70 per cent storage capacity, such as we have outlined, it would not be absolutely necessary to keep more than one stand-by unit hot. This one to be alternated with any one of the other four when it is necessary to clean

(*Continued on page 327.*)

*Paper read at Pacific Coast Gas Association meeting.

Thermal Efficiency of an Oil-Gas Set*

Description of Tests that Have Been Conducted

By E. L. HALL and S. H. GRAF

To many gasmen the term "thermal efficiency" will convey only an academic idea, and it is possible that there may even be some who will conclude from the title of this paper that it is too theoretical to have any practical significance for them. But this is far from true, for even in a small plant the practical possibilities of a thermal inventory or a study of the heat balance may be very great. Certain heat losses may be much larger than suspected and of such a nature that they can be materially reduced, or even prevented altogether.

The present high cost of oil also emphasizes the need for economy in production, and makes an earnest consideration of heat conservation most timely if not actually imperative.

In presenting this subject no effort will be made to avoid technical or even speculative matter, for it is only through visualizing the unknown that improvements and discoveries can be made. The test methods, several of which are novel, are such as can be used anywhere, and they are for that reason somewhat fully described.

Limitations and Scope of the Study

The ideal conditions under which to make the tests needed for a complete heat balance would be a single machine operating continuously and fitted with the necessary means for measuring every item of input, output, and loss. This, obviously, is impossible under operating conditions, and this paper is intended to be not so much a presentation of what might be expected under ideal conditions as it is an investigation of results actually obtained in regular commercial operation. For this reason, the data are taken for the entire plant operating for a whole year, viz., from July, 1920, to June, 1921, inclusive. This data, supplemented by special tests to cover certain points, which will be specially mentioned later, is worked out on the basis of a single cycle for one machine, input and output of this cycle being taken in all particulars as the average over the entire number of cycles, or runs for the year.

Input

Taking up first the consideration of the input we find that for an oil-gas set this includes making-oil, steam, heating-oil, and air. The oil is measured daily in a carefully calibrated tank and the volume is corrected for temperature changes. The oil meter at each generator is regarded merely as an indicating instrument, although it may be stated that a number of these meters have been calibrated from time to time and have been found regularly to give indications correct within about 1½ per cent.

The steam is measured by a flow meter in the line which supplies the generator house. This meter is also known to be sufficiently correct for purposes of such tests as these.

The heating-oil comes from the same tank as the making-oil, and flowing through the same meters at the generators, is not separately measured by absolute volume. The meters at the generators are depended upon to give the relation between heating and making oil.

No meters are permanently installed for measuring the air supply, the figure for air used in this investigation being taken as the average of a large number of tests made on several different machines under various conditions of regular operation.

Output

The output consists of several products as follows:
Purified gas.
Lampblack, which is briquetted.
Tar.

Gas

The purified gas is metered by means of wet-drum station meters, which are periodically calibrated against the works holder and are known to be substantially correct.

Lampblack

To weigh the lampblack direct with any accuracy would be very difficult if not actually impossible. For this reason, and also because an over-all figure was desired, the lampblack weight as used in this investigation is taken from the company's records for the year under consideration. All of the lampblack is briquetted, weighed and sold as fuel, and frequent inventories taken of the stock on hand, therefore it is felt that the figure we are using is more correct than any which we might obtain by other means. The lampblack weight as used is the water-free weight.

Tests were made to determine the amount of lampblack going out with the waste water from the briquetting plant, and it was found to be 1.5 lb. per run, or 0.13 per cent of the total lampblack. This is such a small amount as to be negligible.

Tar

The tar weight is obtained in the same way as that of the lampblack; that is, from a record of sales and comparison of stock on hand. This weight is also water free.

Carbon

There is a certain amount of carbon which is deposited in the machines during each run, and which

*Paper read at Pacific Coast Gas Association convention.

is largely used during the next heating period to heat the machine. Therefore, while this carbon is listed in the following section under losses, it cannot be considered a loss in the strict sense of the word, since a large part of the heat is utilized. The amount of this carbon is determined by difference and is shown in the materials balance for the process.

Losses

In order to check up the heat balance, it was desired that no item of direct heat loss should be determined by difference. For this reason considerable time and effort was spent in determining by actual measurement the radiation and convection loss from the generator shells and their heated projections. Tests were also made for heat carried away by the water circulating through the seal pots, as well as that escaping with the stack gases.

All of the losses will be found fully listed in Table IV and at this point it will be sufficient to indicate only the principal ones, which are as follows:

Heat lost in stack gases.

Heat lost in radiation and convection.

Heat lost in seal pots, or wash boxes due to condensation of steam.

Sensible heat of gas lost by cooling the same in wash boxes and throughout all stages of the purifying process.

Heat lost due to fuel value of hydrogen sulphide, naphthalene, etc., removed in the purifying process.

Heat lost due to opening machine at end of make.

Heat lost in gas wasted in plant.

If all of the items in a heat balance could be accurately determined, the difference between input and output should exactly equal the sum of all of the losses. This is, however, under practical conditions, too much to expect, because many of the items are almost impossible of exact determination. However, even if the check is not exact, errors in individual items are still small enough so that the results will be of practical value.

Materials Balance

In order to present in a comprehensive manner the analyses and amounts of the different materials entering into the process, these data have been tabulated, as shown in Table I, balancing materials into the generator and out from the generator. This table helps in interpreting the quantities involved in the heat balance, given and discussed in the section following this one.

Comparing quantities out of the generator with quantities into the generator, we note that these do not exactly balance, the largest differences being in the excess of carbon, oxygen, and nitrogen. The oxygen and nitrogen are relatively unimportant since they have no heating value. The differences in these cases are probably due to error in the stack-gas analyses. The differences of 37 pounds of carbon per cycle is very important and although it appears and has been listed as a loss, this carbon represents at least in a large measure heat usefully employed in maintaining the machines at working temperatures during stand-by periods.

TABLE I. MATERIALS BALANCE.

Quantities into Generator.

Item	Weight	Carbon		Hydrogen		Oxygen		Nitrogen		Sulphur	
		%	Lbs.	%	Lbs.	%	Lbs.	%	Lbs.	%	Lbs.
Making Oil (Water Free)	3239										
Heating Oil (Water Free)	247										
Total Oil	3486	87.0	3032	11.0	384	0.25	9	0.75	26	1.0	35
Blast Air, Dry	11020					23.2	2555	76.8	8465		
Water in Blast Air	99										
Moisture in Making Oil	81										
Moisture in Heating Oil	6										
Total Steam	1660										
Total Water In	1846			11.1	205	88.9	1641				
Totals In	16352		3032		589		4205		8491		35

Quantities out of Generator

Item	Weight	Carbon		Hydrogen		Oxygen		Nitrogen		Sulphur	
		%	Lbs.	%	Lbs.	%	Lbs.	%	Lbs.	%	Lbs.
Purified Gas	1363	55.0	749	23.6	322	14.0	191	7.4	101		
Lampblack	1165	97.0	1130	2.5	29					0.5	6
Tar	126	91.0	115	9.0	11						
Dry Stack Gases	11059	5.4	598			18.0	1996	76.6	8465		
H_2S Removed	22			5.9	1					94.1	21
Naphthalene Removed	3	93.8	3	6.2							
Water in Stack Gases	603										
*Steam Condensed	1341										
Total Water	1944			11.1	216	88.9	1728				
Totals Out	15682		2595		579		3915		8566		27
Differences	-670		-437		-10		-290		+75		-8

*This item includes water carried away as aqueous vapor in the gas.

Thermal Efficiency of an Oil Gas Set
Aug. 1921

Heat Balance

Tables II and III present a summary of useful heat out, heat in, and of all the losses. All are arranged for easy comparison in four different ways; namely, B.t.u. per cycle, B.t.u. per gallon of making-oil, B.t.u. per thousand cubic feet of gas, and in per cent of total heat in.

Thermal Efficiency

Reference to Table II shows that the over-all thermal efficiency of the process is 72.07 per cent. Of this proportion that which is represented by the heating value of the purified gas is nearly 60 per cent (42.77 per cent of total heat in), while the heat in the lampblack is about 36 per cent of the proportion recovered (26.20 per cent of the total).

Losses

Table III is an itemized statement of the principal losses. These may be studied in more detail by reference to Table IV which appears at the end of this paper. Subtracting the output from the input we find that the difference, or losses, aggregate 27.92 per cent of the total heat supplied. The largest losses are the first four listed, they are:

Radiation and convection.
Heat lost in stack gases.
Heat lost in wash boxes.
Heat lost in carbon deposited.

TABLE II. HEAT BALANCE OF AN OIL GAS SET.

Based on Operating Conditions at Works of Portland Gas & Coke Co. July 1920 to June 1921 inc.

	Item No. Table XI	Items	B.T.U. per Cycle.	B.T.U. per Gal. Water Free Making Oil.	B.T.U. per M of Purified Gas	Per Cent
Heat In	46	Heat Equivalent of Making Oil	60,250,000	149,100	1,200,200	89.90
	51	Heat Equivalent of Heating Oil	4,540,000	11,230	90,440	6.80
	57	Sensible Heat in Oil above 60° F	222,000	550	4,420	0.30
	68	Heat in Steam used	1,940,000	4,800	38,650	2.90
	74	Heat Content of Blast Air above 60° F	49,800	125	990	0.08
	144	Sensible Heat added to Gas by Exhausters	13,600	35	270	0.02
		Total Heat Supplied	67,015,400	165,840	1,334,970	100.00
Recovered Heat Out	25	Heat in Purified Gas	28,644,000	70,900	570,600	42.77
	32	Heat in Lampblack	17,560,000	43,400	349,500	26.20
	36	Heat in Tar	2,070,000	5,120	41,200	3.09
	163	Sensible Heat in Gas out, above 60° F	6,000	150	120	0.01
		Total Heat Recovered	48,280,000	119,570	961,420	72.07
		Total Heat Lost	18,735,400	46,270	373,550	27.93

Thermal Efficiency of an Oil Gas Set Aug. 1921

Analysis of Losses

Radiation and Convection—One of the most evident, although by no means one of the largest ones, is that by radiation and convection from the generator shell and its heated projections. To determine what this loss will be it is necessary to know the heat loss coefficient of the surface, as well as the temperature difference between the generator shell and the surrounding atmosphere. Also, the temperatures of walls or other material objects near the generator have some influence. Values of heat loss coefficient may be found listed in various engineering handbooks, but in making this series of tests it was desired to determine this coefficient rather than rely on these published figures. After making a study of the subject it was decided to use an improved form of the apparatus described in an article entitled "The Practical Efficiency of an Illuminating Water-Gas Setting," by A. G. Glasgow, published in the *American Gas Light Journal*, volume 53, No. 23, Dec. 8, 1890. The apparatus as set up for use is shown in figure 1 and the details of the calorimeter chambers are shown in figure 2. In brief, the method consists in catching the heat radiated over a definite area (two square feet) on a lampblack coated copper sheet which forms one side of a water tank. The convection loss is taken up by a current of air passing through the space between this water tank and the generator shell. During the test run the measured air flow is regulated so that the temperature of the shell under the calorimeter as indicated by thermocouple and potentiometer, remains exactly constant. If the temperature of the water is the same as that of the surrounding objects, the proportion between heat absorbed by radiation and that carried away by convection currents should remain the same as when the calorimeter is not in place. Whether this is exactly true is unimportant, since we are not particularly interested in an exact segregation of these two losses so long as we can determine their sum with precision.

Perhaps it would not be out of place to describe the thermoelectric thermometer used a little more fully. The thermo-couple was a special one made up of two alloys, "chromel" and "alumel." These two alloys give a very high thermoelectric power and are, therefore, well suited for the measurement of medium temperatures, although they are also just as useful, and in fact very much used in measuring temperatures as high as 2,500 deg. Fahr. The cold junction is carried to a thermos bottle. This avoids the need of taking cold junction temperatures and correcting for same, since a thermos bottle under these conditions will ordinarily not vary more than a degree over an entire day. During the course of two or three experimental runs it is not necessary to make any correction whatever. The potentiometer used in a double range set, and will give readings to one-tenth millivolt and by estimation to one one-hundredth millivolt. This is equivalent to 0.4 deg. Fahr., which is sufficient for this work. This entire apparatus was calibrated against a mercury thermometer known to be substantially correct.

Shell Temperatures

It would, of course, be possible to use the thermoelectric thermometer which is described for deter-

mining the shell temperature, but this would involve many readings and would be quite laborious, for the reason that the thermo-couple, in order to give correct indications must be imbedded in the metal of the generator shell. To avoid this, after some preliminary experimentation, it was decided to employ the principle of the electric resistance thermometer. Figure 4 shows the arrangement finally used. Beginning at the floor line the generator shell was encircled at every five feet with a No. 30 single cotton-covered copper wire of which the resistance had first been determined at a known temperature. The ends of these loops of wire were brought to a set of leads which could be short-circuited by means of a copper link, the leads then being carried to a Wheatstone bridge provided with a suitable galvanometer and battery. To make a determination of temperature with this arrangement the leads were first short-circuited and their resistance determined. Next, combined resistance of the loop and leads was taken and corrected for lead resistance. This gave the net resistance of the loop from which the temperature could be calculated by using the well-known equation for resistance of a conductor at various temperatures. ($t = t_0 + Rt - R_0 \div kR_0$.) t = temperature to be determined. t_0 = some known initial temperature at which the resistance of the conductor is found to be R_0. Rt = resistance at t. k = resistance coefficient per degree.

Heat-Loss Constants

Figure 3 gives curves showing the constants for heat loss by radiation, convection, and by both together as determined by all our tests. These, of course, are average figures for our particular conditions and would have to be used with caution if applied elsewhere. Considering the constant for total heat loss this would be used in the following manner:

Suppose the temperature of the shell is 300 deg. Fahr., then the loss per degree difference between shell temperature and air temperature per square foot of generator shell per hour would equal 4.07 and the total loss would be this constant multiplied by the temperature difference, the generator area in square feet, and the time under consideration in hours. To show the practical application of these principles the following discussion and illustrative examples are offered.

What is commonly referred to as the loss by "radiation and convection" is really a loss due to transmission. The amount of this loss depends primarily on the thermal resistance of the generator lining, and the generator shell will assume a temperature sufficiently above that of the surrounding air and material objects to dissipate by radiation and convection the heat transmitted. The more perfect the insulation, the less will be the amount of heat transmitted, and hence the temperature of the shell. Since the heat lost increases very much more rapidly than the temperature difference required to dissipate this heat the benefit indicated by a reduction in shell temperature may be much greater than suspected. The following experimentally determined figures applying to the shells at the Portland Gas & Coke Company's works are a striking illustration:

Shell Temp. Deg. Fahr.	Difference Deg. Fahr.	Constant (See Fig. 3)	Loss in B.t.u. Per Sq. Ft. Per Hr.
100	25	1.70	42
150	75	2.20	165
200	125	2.70	338
250	175	3.30	578
300	225	4.08	920
350	275	4.90	1,350

The lining in these generators consists of 13½ in. of firebrick and 3 in. of asbestos. The resistance of the shell itself is very small and may be neglected. The foregoing figures are for average conditions and include tests on some shells in relatively poor condition.

The laws of heat flow are analogous to those for electricity and we may say that

$$Q = t \div R$$

Where Q = heat flux in B.t.u. per sq. ft. per hour, "t" is the difference in temperature between the in-

TABLE III. ITEMIZED STATEMENT OF PRINCIPAL LOSSES IN OIL GAS SET.

Based partly on special tests and partly on operating records at works of Portland Gas & Coke Co. from July 1920 to June 1921 inc.

Item No Table IX	Items	Btu. per Cycle	Btu. per Gal. water Free Making Oil.	Btu. per M of purified Gas	Per Cent.
88	Total Heat lost in Stack Gases	4,859,500	12,000	96,900	7.24
93	Radiation and Convection	926,300	2,280	18,420	1.38
132	Total Heat lost in Wash Box	5,086,800	12,580	101,400	7.59
176	Heat in Carbon Deposited and Unburned	6,360,000	15,700	126,900	9.48
	Heat lost in Cooling Gas beyond Wash Box	95,200	234	1,890	0.14
153	Heat Value of Naphthalene removed	25,100	62	500	0.04
159	Heat Value of H_2S removed	164,000	405	3,270	0.24
158	Heat Value of Gas lost in Plant	10,800	27	215	0.02
180	Heat lost due to opening of Machines	329,000	812	6,555	0.49
	Total Losses determined	17,856,700	44,100	356,050	26.62
	Total Losses by difference. See Table II	18,735,400	46,270	373,550	27.93
	Not accounted for	878,700	2,170	17,500	1.31

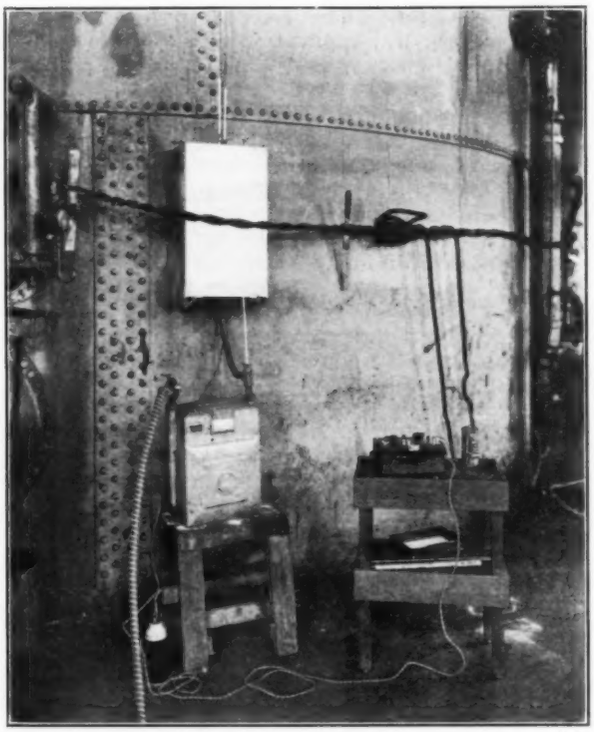


Figure 1—Calorimeter for radiation and convection in use, showing method of measuring shell temperature with thermo-couple and potentiometer

side of the generator and the air outside in degrees Fahrnheit, and "R" is the thermal resistance equal in $(a \div k_1 + b \div k_2 + \ldots\ldots)$ where a, b, c, etc., represent the thicknesses in feet, and k_1, k_2, k_3, etc., the thermal conductivities of the different components of the lining. Applying this equation to the lining described, we have:

$$Q = \frac{1{,}700 - 75}{(1.12 \div 0.75 + 0.25 \div 0.12)} = \frac{1{,}625}{3.58} = 453,$$

which gives the theoretical figure for heat loss to be compared with 566 as determined by experiment. The difference may be accounted for by the coefficients (0.75 for firebrick and 0.12 for asbestos) obtained from Marks' "Mechanical Engineers' Handbook" (tables 20 and 21, pages 304 and 305), being low, or possibly there may exist in the practical case some leakage of hot gases from the generator interior through the firebrick lining. However, the agreement is close enough for purposes of comparison.

Possible Saving

To indicate possibilities let us now consider a lining of 9 in. of firebrick, 4½ in. of diatomaceous earth blocks and 3 in. of asbestos. In other words, replace the outer course of firebrick with an insulating brick. For these conditions we have

$$Q = \frac{1{,}700 - 75}{(0.75 \div 0.75 + 0.37 \div 0.07 + 0.25 \div 0.12)} = \frac{1{,}625}{8.36} = 194$$

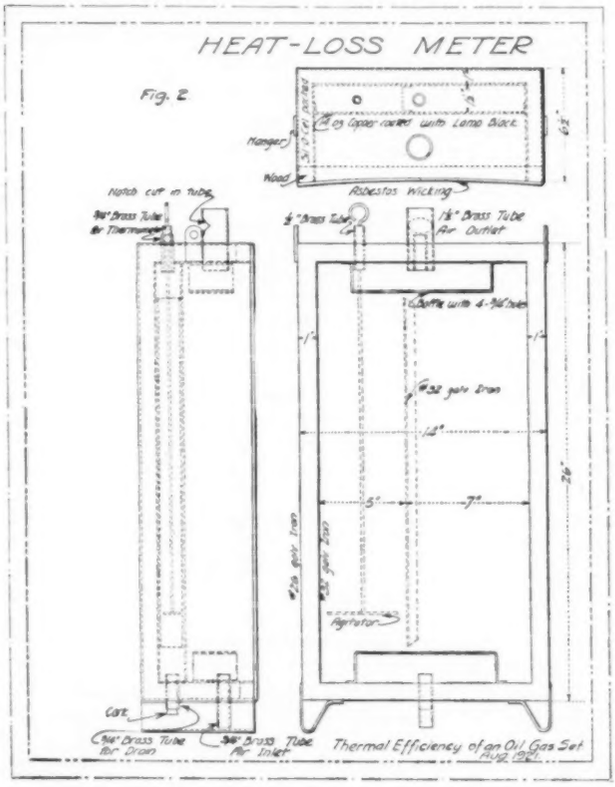
The generator shell will attain a temperature sufficient to dissipate this quantity of heat, and reference to the table in paragraph 5 of the preceding section will show that this temperature will be about 160 deg. Fahr.

Using a lining of 9 in. of firebrick, 9 in. of diatomaceous earth blocks, and no asbestos gives a value for "Q" equal to 139, and a shell temperature of about 140 deg. Fahr. Other, and perhaps more practical or less costly, combinations will no doubt suggest themselves.

The saving in heat resulting from a use of the combination just considered should be equivalent to

$$\frac{(453 - 139) \times 2{,}747 \times 24 \times 365}{18{,}600 \times 8 \times 42}$$

or 1,207 bbl. of oil per year per generator kept continuously heated. At $2 per barrel this is $2,414.



Not only is the possible monetary saving considerable; working conditions about the machines would also be improved.

Heat Loss in Stack Gases

It is apparent to any one observing the operation of a gas works that there is a considerable heat loss

(*Continued on page* 328.)

Old-Age Meter Changes

A Careful Study of This Much-Discussed Matter

By C. R. MILLER

Superintendent Utilization, Portland Gas & Coke Company, Portland, Ore.

The great importance of the proper registration of a gas meter both to the utility, from the standpoint of revenue, and to the consumer, from the standpoint of high bills, has made the subject take first place in connection with the regulations for service prescribed by the various State commissions.

The question of accurate registration in connection with these regulations has heretofore been closely associated with the length of time that the gas meter has been left in service

Hence certain rules have been established, designed to retire meters from service after a certain period of time. The general practice differs in the various localities, but apparently is based on general experience rather than on a scientific analysis of the conditions.

It is the attempt of this paper to show that, so far as the experience of the Portland Gas & Coke Company indicates, there appears to be no necessary relationship between the accuracy of a gas meter and the period in service.

Since the general tendency of gas meters is to run slow, the consumer would, generally speaking, appear to have the advantage, except in isolated instances. Under average conditions, therefore, from a consumer's standpoint, there appears to be no necessity for regulations limiting the period of service and automatically retiring the meter for repairs.

On the other hand, the problem of old-age meter changes, from the gas company's standpoint, not only involves losses in revenue through slow or D. R. meters, but represents the largest single item of expense in connection with meter traffic from an operating cost standpoint.

The regulations governing meter changes for old age vary somewhat with different States in the Union, in accordance with the tabulation appearing at the end of this page. It will be noted, however, that the majority of States provide for a periodical test every five years.

It is the writer's contention that none of these regulations is based upon a scientific consideration of the subject, and that the period after which meters should be changed depends entirely upon local circumstances, which should be examined into in the case of each utility.

In view of the large annual expense in connection with the retirement of old-age gas meters, there would appear to be in an arbitrary regulation of the period a great liability to unnecessarily expend a large sum of money in operation, without particular benefit either to the consumer or the company.

We will attempt in this paper to analyze the problem with respect to meter conditions of the Portland Gas & Coke Company, not with the idea that the conclusions will necessarily apply to all utilities, so far as the exact period at which meters should be changed is concerned, but rather by way of illustrating that there does not exist any necessary relationship between the period of service and the correct registration of a meter.

The evident fact that the author has given considerable time, thought and care to the preparation of this article warrants a serious reading. The paper was presented at the last annual meeting of the Pacific Coast Gas Association.—Editor.

For the purpose of determining how long a meter could remain in service without the need of mechanical adjustment or repairs, or undue loss from a registration standpoint, records of the Portland Gas & Coke Company were examined on all meters removed from consumers' premises during the twenty-two consecutive months immediately preceding December, 1916, as shown in Table No. 1.

In this survey 16,184 meters of all sizes were tabulated, but in order to avoid invidious comparison between various makes of meters the Maryland type, consisting of 9,860, or 58.7 per cent

States	Service Allowed
Illinois	7 years
New York	7 years
California	6 years
New Jersey	6 years
Colorado	5 years
Connecticut	5 years
District of Columbia	5 years
Indiana	5 years
Kansas	5 years
Missouri	5 years
Montana	5 years
New Hampshire	5 years
North Carolina	5 years
North Dakota	5 years
Oregon	5 years
Pennsylvania	5 years
Washington	5 years
West Virginia	5 years
Wisconsin	4 years
Arizona	3 years
Nevada	3 years

of the total, was alone considered. In order to check this first tabulation a similar analysis was made for 1919 and 1920, covering the removal from service of 17,704 Maryland meters which had been in service for periods ranging from a part of one year to as long as thirteen years. This tabulation is given under the head of Table No. 2.

TABLE NO. 1

Average Per Cent Fast or Slow of Meters, January, 1915, to November, 1916, Showing Repaired Meters for 22 Consecutive Months and Different Ages

Years	Maryland
0	—0.85
1	—0.22
2	+0.50
3	+0.19
4	+3.96
5	—1.41
6	—1.25
7	—1.29
8	—2.35
9	+1.20
10	+2.00
Yearly average (per cent)	—0.034
Weighted average (per cent)	—0.167
Profit or loss per 1,000 cu. ft. (in dollars)	—0.00167

TABLE NO. 2

An Analysis of Monthly Meter Test Reports for 1919 to 1920 (Type of meter—Maryland)

Years	No. of Meters	Per cent Fast of Slow for Different Yrs. of Service
0	3,111	—0.70
1	3,507	—0.39
2	2,260	—0.04
3	2,178	+0.07
4	1,484	—0.13
5	1,172	—1.23
6	848	—0.34
7	729	—0.33
8	1,670	—0.89
9	443	—1.35
10	267	—4.20
11	27	—1.00
12	6	—0.29
13	2	—1.30
Weighted average, per cent slow		—0.54
Total number of meters		17,704
Per cent of total		81.2

Remarks: Figures 0 to 13, inclusive, indicate the number of years the meters represented had been in service. A notation of (—) minus means slow, of (+) the per cent fast. All figures are from a basis of 1 per cent; for example, —11.50 means 11½ per cent slow. All meters herein considered have been tested at six times their rated light capacity, and computations based upon such test results with the exception of those proving slow in excess of 50 per cent, which were considered D. R., or 100 per cent slow.

It will be noticed that both tabulations reveal about the same situation.

An examination of the tabulations does not reveal any progressive relationship indicating that the meters become more or less accurate the longer they have been in service. In neither tabulation is the year of maximum inaccuracy the same.

On the other hand, if we exclude the D. R. meters the comparison becomes still more striking, and it is evident that the greater inaccuracy, if any, on account of the term of service is greatly influenced by the number of D. R. meters which are excluded in the following tabulation:

TABLE NO. 3

An Analysis of Monthly Meter Test Records for 1919 and 1920, Excluding All D. R. Meters

Per Cent Fast or Slow for Different Years of Service

Years Service	Total No.	Inc. D. R.	No D. R.	Exc. D. R.
0	3,111	—0.70	32	+0.33
1	3,507	—0.39	30	+0.56
2	2,260	—0.04	15	+0.62
3	2,178	+0.07	9	+0.48
4	1,484	—0.13	9	+0.48
5	1,172	—1.23	16	+0.13
6	848	—0.84	18	+1.28
7	729	—0.33	4	+0.22
8	1,670	—0.89	13	—0.11
9	443	—1.35	2	—0.90
10	267	—4.20	6	—1.95
11	27	—1.00	1	+2.70
12	6	—0.29	..	—0.29
13	2	—1.30	..	—1.30

The statement hence may be made that, so far as the records of the Portland Gas & Coke Company would indicate, a meter does not progressively become less accurate due to the length of time in service. It may be stated as a logical deduction that this will be true of a similar type of meter no matter where installed, under similar conditions, and we may draw the final conclusion that any system of regulation based upon the assumption that meters necessarily become more inaccurate the longer they are in service is based upon faulty premises.

It is seen, therefore, that any regulation that may be established for the removal of meters due to old age should be established entirely upon an examination of the records of that particular utility and the conditions under which these meters must operate.

To illustrate the lack of reason in such regulations as are now in effect, let us consider human beings instead of gas meters. Should we find upon examination of insurance of other statistics that a certain number of human beings at a certain age become diseased in a certain way, are we justified in sending all human beings to a hospital for the treatment of such a disease at the end of the indicated period?

On the other hand, is it not much more logical to send a human being to the hospital when symptoms appear? Even if we should establish similar regulations for human beings as for gas meters, should we not take into consideration, in establishing such regulations, the local health conditions to which the individual is subjected to?

Averages Are Misleading

The study of averages is a very misleading study. An average condition may be produced either by slight imperfections in many units or by large imperfections in a few units. If it can be scientifically shown in the case of gas meters that condition of inaccuracy is produced by the imperfection of a few meters, then it would seem more logical to attack the problem of securing a correct registration by some other means than by a wholesale removal of meters.

When the gasman succeeds in collecting and present-

(*Continued on page* 335.)

As the Journal Views It

TABLE OF CONTENTS

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Municipal Ownership to the Front

It would seem that the public utilities of New York State, and New York City in particular, are to be made the playthings of politics to an even greater degree than they have been heretofore if the announced plan of the Transit Commission regarding the handling of the New York street railway, subway and elevated situation is to be taken seriously. Apparently it is for the great metropolitan newspapers almost without exception hailed the plan as being the only solution of the difficulty. This plan, briefly, has as a basis the turning over of the railway systems to the City of New York under a municipal ownership plan and the operation by three corporate agencies to be created for the purpose.

While this plan differs somewhat from that proposed by the other political fraction which at the present time is in power in New York City, it is sufficiently alike to be confused in the minds of the general public.

But this is not the main point. It becomes almost a certainty that there will be more definite moves made by politicians of both parties for the ownership and operation, in many cases of every other public utility of no matter what class of service.

The scheme is advanced by men of high standing in the community but despite this it has the taint of being a political expediency that will aid in the election of new city officials. In fact, the AMERICAN GAS JOURNAL is greatly surprised to learn from authoritative sources that the plan has been devised by men, one of whom, at least, is connected with a large public utility but who evidently is using his every endeavor to get back in the political game. The other general gentlemen, we venture to say, are not experts, even though they are greeted as such. They are men of wide experience, it is true, but their connection with the public utility field has been, to say the least, delightfully vague and indefinite.

We feel that gasmen cannot ignore the tendency that is being shown to force public utilities into the hands of politicians. We have had our experience of Government operation and, even though it may be called by another name, the same considerations will animate every move of a so-called "corporate operating agency." We would say, in fact, that at least one gentleman evidently is trying already to play both ends against the middle with the hope of personal reward.

There is no room or excuse for any such plan as that outlined by Governor Miller's Transit Commission. It is wrong on its very face and cannot work other than to the detriment of both the city and the transit systems. Unless the plan is materially altered then public utilities in New York State, to say the least, are facing the greatest fight in their history for their very existence.

But there is one slight ray of hope. That rests in the fact that the plan has been advanced far enough before election to allow for a change. After the plan has been thoroughly digested by the public and is considered in relationship to what has gone before there undoubtedly will be raised a general cry that will at least give pause to the politicians. But even this hope is very slight, for the newspapers have jumped to conclusions and have determined to support the plan, even though they are finally convinced that it is wrong. There are many considerations entering into this, not the least of which is the opposition to the present administration in New York City. The AMERICAN GAS JOURNAL is as strongly opposed to the present administration as is any other publication but it also sees the other side of the question, and that side is that the present plan is wrong, all wrong.

Gasmen must guard against any such unwarranted interference with utilities, for it is the beginning of the end. Anyone who is connected with the public utility business, and now we have particular reference to those connected with gas companies, in no matter what capacity, are simply proving themselves unworthy of a place in our field by their advocacy of the Miller transit plan.

Business Conditions and Unemployment

That the turning point in the unemployment situation has been reached is the conclusion of many who are in close touch with the problem, according to information obtained by the AMERICAN GAS JOURNAL. They base their arguments on the fact that there is little heard of threatened strikes or lockouts and instead there is rapidly being arrived at a sane basis of agreement between employee and employer. With this to work on, business men feel that they will be

able to live up to any contract that they may make and so they are going after business in an active way. This is bound in itself to create prosperity.

But labor experts are of the opinion that there has been too much written about the period of depression. They believe that this has caused a feeling of timidity and has reacted unfavorably so far as a resumption of normal progress has been made. Then, too, the conferences that have been called in various parts of the United States, including that at Washington, have attracted widespread attention and the jobless have felt that they need not make any effort to seek work for themselves but that in some manner the various branches of the Government would see that they were supplied with nice, easy work at high wages. It is to be hoped that instead of making plans that will react unfavorably on business that there will be a decided stand that a man should get out and hustle for himself. This in itself is bound to improve the business situation.

Looking at it from a utilities standpoint, the laboring situation should of itself clear up and undoubtedly many men who left companies when they were able to command war-time wages greatly in excess of what we could pay, will be willing to return for a living wage and to give full value for the money paid. After all, that is the crux of the matter: getting value for the money paid out.

Risk in Handling and Storing Coal, Oil and By-Products

(*Continued from page* 316.)

hydrant and hose water protection for cooling the sides of any burning tank and protecting surrounding property.

"I suggest that you refer to the 'Rules and Requirements of the National Board of Fire Underwriters for the Storage and Use of Fuel Oil,' 1920 edition, as most of the recommendations are applicable to gas oil."

As for the storage of oils, the Fire Prevention Commission of Massachusetts have drawn up articles for storage and handling of oils both of an inflammable nature, such as naphtha gas, etc., and also the heavier grades of gas oil, fuel oil, etc. These State regulations are practically the same as the insurance companies' regulations, except in a few points, which are as follows:

1. Distance of tanks from building.
2. Lightning protection on steel tanks.
3. Type of construction of dikes surrounding the storage tanks above ground.

As for the regulations for the storage, handling and use of heavier oils, the following are the regulations drawn up by the Boston Board of Fire Underwriters, which were adopted by the Massachusetts District Police and became effective Jan. 1, 1920. They are applicable to liquids having a flash point above 150 deg. Fahr. The regulations specify the following:

1. The circulating pump must be located above the highest oil level of the oil storage tank and all of the piping pitched, so they will drain into the storage tank.
2. The suction and discharge lines must enter and leave the top of the oil storage tank.
3. Filling and suction pipes must extend to the bottom of the oil storage tank.
4. Direct flow from an overhead tank to a surface tank is not permitted. However, this is sometimes allowed when a pump intervenes.
5. Each storage tank must be provided with a manhole and vent pipes with brass mesh screen.
6. Each storage tank must be provided with a steam fire prevention pipe
7. Check valves must be placed in pipe lines as close to the oil storage tanks as possible to avoid siphoning.
8. Valves must be placed in suction and discharge lines to and from the storage tank, as close to the tank as possible.
9. Overhead tanks must be provided with a dike of 150 per cent capacity. The height of the dike is to be not more than one-quarter of the height of the tank. If the dike is made of earth the slope must be two to one and the pipes may be below the top of the dike.
10. Underground storage tanks must be covered with at least three feet of earth.
11. Each installation must be approved by the authorities on its merits. In an isolated location, certain modifications of these requirements are permitted, except in Massachusetts.

Tars and Heavy Oils

Fuel oils, if used for steam purposes in boiler furnaces, offer some hazards to firemen from "flashbacks" in the burners or explosive mixtures in the furnaces accumulating before ignition.

Tarry Residues a Menace

Coal and water gas tars, if properly confined, are not much of a fire risk, but tarry residues or spill, if ignited in open tanks, offer a very serious fire menace. The acrid and very dense fumes from tar fires make them one of the most difficult fires to fight. Water is not a very good medium for extinguishing such fires unless the tar is confined and there is room for flooding water on top of the tar, thereby excluding the air.

Tars, especially coal tars, burn the skin of workmen and, if particularly aggravated, burns result in foreign growths, like keloids, which may mean operations on the affected parts.

The same burns sometimes result from the handling of light oils, like benzol, toluol, xylol, naphthas, drip oils and naphthalenes.

This group of substances also are very volatile and evolve large quantities of vapor at ordinary temperatures. They are, therefore, very inflammable, and constitute the greatest fire hazard to a plant if stored in very large quantities. During the war times many plants had to use special precautions with respect to fire hazards caused by the manufacture of these oils. Due to market conditions to-day, however, very little

of this material is stored in gas company plants.

Ammonia is not combustible, but if fire starts and the heat is sufficient to evolve the ammonia gases from any ammonia compounds in the vicinity, the fire fighters are seriously handicapped by the suffocating ammonia gas.

Coke

Coke does not materially increase the fire risk of a plant, and if coke is ignited the fires are easily extinguished by water.

Coke handling, however, does cause numerous injuries to workmen because of the sharpness and hardness of the lumps. They cause cuts on feet improperly shod and cuts on hands. Falling lumps from overhead handling are a source of danger. Fine coke dust is a source of many eye injuries, due to its hardness and sharpness, cutting the eyeball if not immediately removed.

In some plants, hot coke operations cause burns to workmen.

Spent purification material (iron oxide and shaving mixtures) often contain over 50 per cent by weight of free sulphur. This material, if ignited in any way, or if fired from spontaneous heating within the batch itself, makes a very stubborn fire to extinguish, due to the sulphur fumes, affecting the workmen.

The firing of this material can be done in the purifiers if when revivifying the foul oxide too rapid a flow of air or too much air is passed through. The ignited sponge then is a source of danger from explosion of gas and air mixtures when gas is turned through the mass.

Gas Holders

There have been accidents known to happen to gas holders, some due to fire and some due to rupture of the shells from one cause or another. Gas holders are frequently struck by lightning during thunder showers but, being as a rule perfectly grounded, no damage results. There is one case of a fire which occurred in Springfield, Mass., some years ago, which may interest you.

The information is from the insurance company's inspector's report. He got his information from the chief engineer of the street railway company, who stood on a coal trestle at the same level as the holder and was an eye witness of the accident.

A 300,000 cu. ft. holder was destroyed by fire caused by lightning. This holder was surrounded by a cylindrical brick building with a conical roof built of wood covered with slate. The wooden rafters of this roof rested on the brick wall at the base and were supported at the peak by a wooden ring. Upon this ring rested a ventilator, also built of wood; on this ventilator was a lighting arrester which was evidently defective. The lightning struck the ventilator, setting it on fire. This burned down until it burned the rafter support; when this occurred the roof collapsed and one of the rafters ripped a hole in the top of the holder, allowing the gas to flow out and become ignited by the fire in the ventilator. This burned up in one column of flame reaching above the powerhouse smoke-stack which is 225 ft. high. The valves were shut on the holder and the fire burned itself out. Although this holder is one of a nest of three, neither of the other holders were injured by the heat. A 2,000,000-ft. holder only twenty feet distant from the one destroyed had a considerable number of brick thrown into the pit from the wall of the building, which was pushed over when the roof fell, and these were removed later by a diver.

At first it was thought that there was an explosive mixture in the building, but this was not a fact, as the ventilator burned for twenty minutes before the roof fell. There was no explosion at any time, simply one long column of flame until all the gas was consumed.

Since there is no oxygen stored with illuminating gas, an explosion from ignition is very unlikely. In many cases where gas-holder fires have occurred, the gas burns at the place where it escapes into the air from the holder, until all of the gas is consumed. Quite often the gas has been taken out from a burning gas holder and pumped to a place of safety.

Gas Holder Capacity vs. Generating Capacity

(*Continued from page* 317.)

sprays or a wash box, or make repairs. This arrangement makes it possible to shut down each unit every three or four days. The sixth generator should be kept ready, during the two months of maximum output, to make gas on short notice, although it may never be used throughout the whole season.

Relation of Generation and Storage Capacity

One point that I want to bring out very decidedly is the very definite relation between generation capacity and storage capacity regardless of the size of the plant and the amount of the maximum output. This definite relation is required in order that the greatest generating efficiency may be obtained. Storage capacity should always be great enough so that when a generator or generators are started it will be possible to maintain continuous operation until the day's work is done and not have to be shutting down an hour or two or three during off hours because the holder is full. This applies whether the day's work is twelve, sixteen or twenty-four hours long. In a small plant, where one generator will make sufficient gas for the day's output in fourteen or sixteen hours, the storage capacity should be enough so that the generator could be started in the morning when the day's send-out began, and continuous operation maintained until 10 or 11 P. M., with no shutdown in the afternoon because the holders are full. In larger plants, where several generating units are operated day in and day out, the storage capacity should be sufficient to give plenty of room in off hours to keep the correct number of units generating straight through the twenty-four hours. Make the storage take care of the peaks and valleys in the send-out curve and earn interest on the investment the holders represent by saving oil per 1,000 on the gas made through continuous operation of the generators.

If there is anyone who does not think there is a great deal of difference between continuous and intermittent generation let him make careful note of the efficiency of his plant next winter from day to day, when he has the opportunity.

Suppose it costs you as small an amount as one-tenth of a gallon per 1,000 to operate with frequent

shutdowns; the average daily output is 10,000,000 cu. ft.; oil is worth $1.75 a barrel. This little one-tenth of a gallon per 1,000 represents an annual loss of over $15,000, or 7½ per cent on $200,000. Considerable addition could be made to the storage of a plant this size for half that amount.

When the growth of the business warrants an increase in the size of the plant, it would be best to add to both generating equipment and storage holders so as to maintain the same proportions as outlined above. If money and material are expensive and hard to get, then for economic reasons it would not appear to be good business to make any but the most necessary expenditures. Such being the case, build generators first, and when conditions warrant, increase storage capacity.

Why generators first? Because they are the very life of the plant; the gas cannot be sold until it is made. No matter how much the storage tanks hold, if the generating units are crippled and overloaded to a point where each day shows the holders a little lower, then it is only a question of time until the town goes out of gas. On the other hand, should anything go wrong with the holders there is always the by-pass which can be opened and with ample generating capacity the town can be supplied with gas indefinitely. Perhaps the service will not be 100 per cent but it will be a great deal better than no service at all.

That is why generators should be the first consideration in plant extension. But if both generation and storage are needed to anticipate the increase in business, then it is up to the engineering department, through the executive officers, to convince the finance committee that the expenditures must be made even if the money market is out of balance. It is all right to take a chance sometimes, but not with the reliability of the gas service to the consumer. It means too much to him and to the utility itself.

In conclusion, storage capacity should be 65 to 70 per cent of the peak day's output. This amount gives an ample factor of safety at all times and also gives sufficient leeway so that generating may be carried on most efficiently. Active generating capacity for actual operation should be 10 to 20 per cent greater than the average daily send-out, thus giving sufficient reserve capacity to take care of the peak days. Size and number of auxiliary generators will depend entirely on the size and number of units in operation. But in any event the stand-bys should have a capacity not less than 25 per cent of that of the operating units; from that up to 50 per cent.

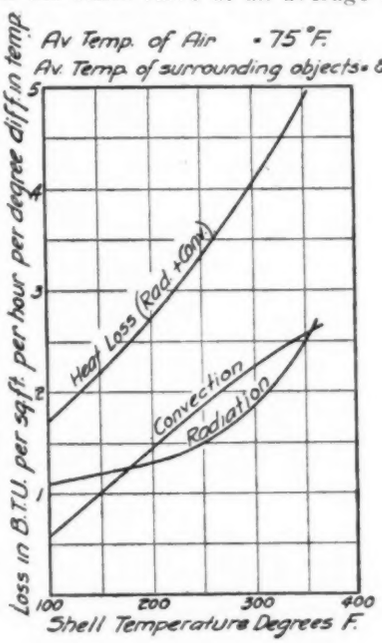
Thermal Efficiency of an Oil-Gas Set

(*Continued from page* 322.)

during the heating period in the cycle of operation of a gas generator and the thought which naturally occurs to the engineer is that there should be some way in which to utilize this waste heat. Reference to table III shows that this loss amounts to 4,859,500 B.t.u. per cycle or 7.24 per cent of the total heat supplied. This is a very large loss and, of course, could not be entirely recovered by any means which could be applied in practice. There are two schemes which suggest themselves as offering a possibility of saving. The first is the use of waste heat boilers which have been quite extensively applied to cement mills and metallurgical works of various kinds. In these cases the flow of highly heated combustion products is usually either continuous or at least of considerable duration. In cases of a gas set this is not so as the cycle is such that the flow is intermittent. However, by combining the effect of a number of generators it is possible to obtain a more or less continuous flow of heat. With the idea of investigating the possibilities along these lines a study of available power was made, a resume of which is presented in figures 5 and 6.

Power Available from Waste-Heat Boilers

As shown by figure 5, products of combustion issue from the stack valve at an average temperature



HEAT LOSS CONSTANTS FOR GENERATOR SHELL

Fig. 3.

of 1,434 deg. Fahr. The temperature of the flue gases issuing from waste-heat boilers would probably not be higher than 600 deg., nor lower than 500 deg. Taking the latter assumption, the average boiler horse-power (34.5 lb. of water evaporated from and at 212 deg. Fahr.) available during the heating period is 486. Referring to figure 6, it is noted with three generators operating the flow of heat and consequently the boiler horse-power available would be fairly uniform and continuously equal to the amount stated. With six generators operating, the continuous average power would, of course, be double this amount. As a matter of further interest, it may be stated that this steam is about equal to that generated by our present boiler plant so that it appears that waste-heat boilers would probably supply the steam requirements of the process and the works generally. However, it must be stated that an installation of waste-heat boilers would be quite complicated mechanically and quite costly.

Preheated Blast Air

The second idea which suggests itself as a possible

means of utilizing heat from the stack gases is that of applying the regenerative principle of preheating the blast air. Figure 7 illustrates this idea in a diagrammatic way. The set is shown in the heating period of the cycle with blast air entering at "A." This air takes up the heat stored in the regenerative checkers from the previous heating period, passes on through the chamber "C," where it meets incoming heating-oil or unites with carbon deposits from the previous make, then on through the set, becoming highly heated, until it reaches the regenerative checkers in the left-hand unit of the set. Here part of the heat is absorbed and stored for utilization in the next heating period when the blast is admitted at "B," with stack valve "D" closed and stack valve "E" open. The amount of heat stored up and the exit temperature of the gases will depend, of course, on the amount of regenerative checker-brick. There is no doubt that this scheme would effect a large saving in heat, and it would also appear to have advantages in the way of maintaining a more uniform temperature in the making checkers. It is possible, too, that this scheme could be combined with waste-heat boilers or at least economizer sections for heating boiler feed water so that a still greater proportion of the heat could be saved.

Heat Loss in Wash Boxes

The heat carried away by the water flowing through the wash boxes comes from the cooling of the gas, lampblack, and tar, from the average temperature in the offtake, which is 1,710 deg., down to the temperature of the out-flowing water, which is about

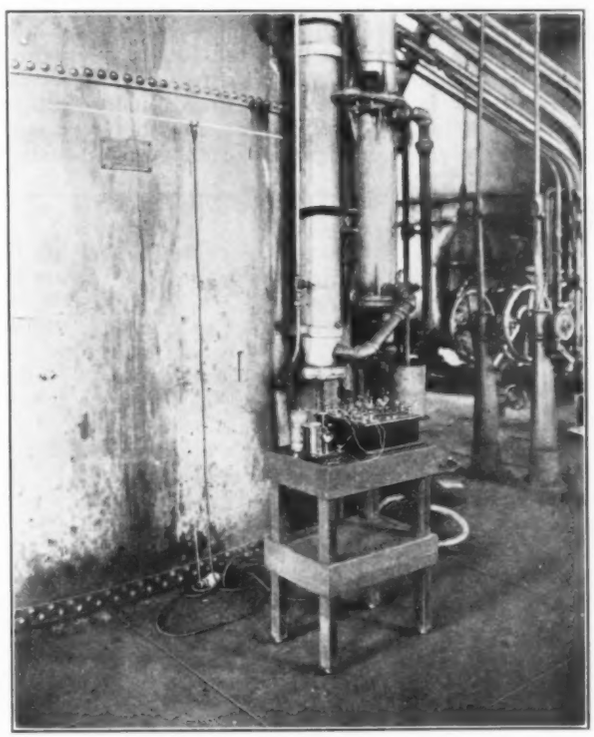


Fig. 4—Electric Resistance Thermometer for Measuring Generator Shell Temperature

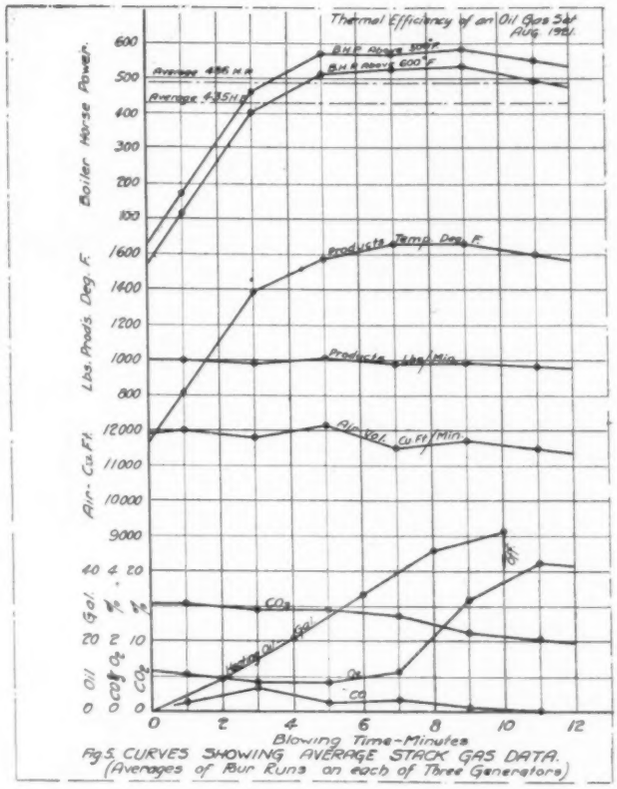
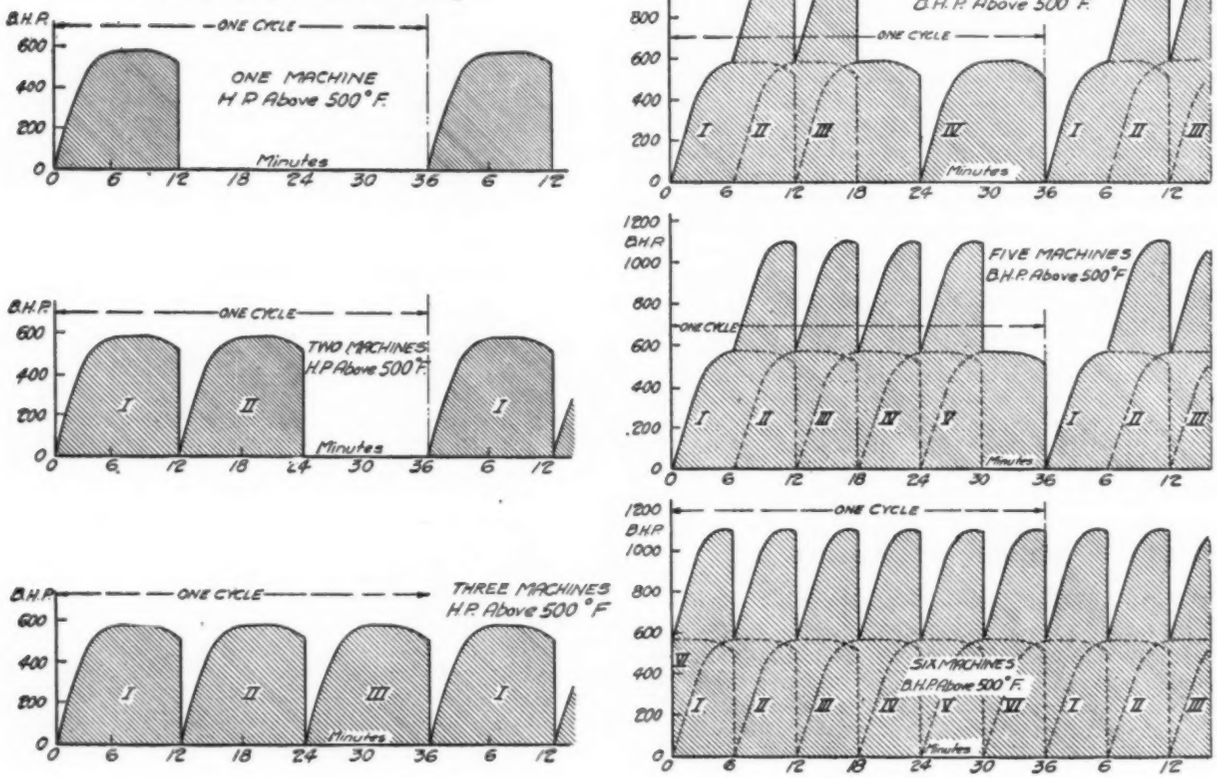


Fig 5. CURVES SHOWING AVERAGE STACK GAS DATA. (Averages of Four Runs on each of Three Generators)

140 deg., and from the condensation of the excess steam used during the making and purging periods. Theoretically it would appear that the sensible heat of the gas might be utilized, but practically on account of the large quantity of lampblack which is present and which must be separated at this stage of the process, it is very doubtful if it would be practical. The heat from condensation of the excess steam amounts to 2,475,000 B.t.u. per cycle. This is a very large amount and it is quite probable that a saving could be effected by cutting down to the lowest possible point the amount of generating steam. Some calculations which we have made indicate that the amount of steam which is being used is not very much more than that which is needed for effective atomization of the oil and for cooling the oil spray nozzles sufficiently to keep them from being damaged by the heat when not in use. It is possible that mechanical spraying of the oil by means of sprays made of some high melting point alloy could be used to effect a great reduction in this loss. It is proposed to make some experiments along these lines.

Frequently the only heat loss that is considered in connection with the steam is the heat content of the steam as it enters the machine, but this is by no means the entire loss. The heat content of the total steam entering the machine is 1,940,000 B.t.u. while the heat content of the part of this steam which leaves the machine in the wash boxes and in stack gases amounts to 2,962,000 B.t.u. or a gain of 1,022,000 B.t.u. which the excess steam has stolen from the machine. This emphasizes the need of steam economy and it is probably along these lines that the greatest saving can be made in the heat lost in the wash-box water.

Fig. 6.
AVERAGE AVAILABLE POWER
Waste Heat Boilers with Different Numbers of Generators Working.



Measurement of Wash-Box Water

The water coming from the wash boxes flows through a flume of considerable length. The method used in measuring this water is one which was applied by the junior author in certain other tests made during the summer of 1920, and is of such general applicability that it is believed worth while to describe it in some detail. The fundamental principle upon which the method is based is that the electrical resistance of water is greatly lowered by the addition of a relatively small amount of an electrolyte such as a brine solution or dilute acid. In the case of an open flume or channel of any kind, the manner of making the test is as follows:

One observer is stationed up stream where at a given moment he pours into the stream a quantity of the brine or dilute acid, at the same time starting a stop watch. A measured distance away (say 100 or 200 ft.) another observer is stationed with an electrical detector built along the lines illustrated in figure 8. When the slug of saline or acidulated water reaches observer No. 2, the resistance between the electrodes is lowered and the millivolt meter will show a sudden increase of deflection from A to some point B. At this time observer No. 2 signals observer No. 1, who stops the watch. The distance between stations divided by the number of seconds gives the velocity in feet per second, which multiplied by the cross-section area of the stream in square feet gives the quantity of flow in cubic feet per second, which may then be reduced to any other desired units, such as gallons per minute, etc. Of course, there are some small errors in this method, due to the diffusion of the chemicals and personal equation of the observers. Corrections may be applied for these but for ordinary tests this is not necessary as the accuracy even without correction is sufficient for ordinary plant tests.

Heat Lost in Carbon Deposited

Carbon deposited in the machines is one of the largest losses in the process. Of the total carbon entering into the machine, or 3,032 lb. per cycle, we have accounted for 749 lb. in the gas, 1,130 lb. recovered as lampblack, 115 lb. in the tar, and by calculation from stack gas analyses have determined that 598 lb. are usefully employed in heating the machine, thus leaving a balance of 437 lb. not accounted for during the stand-by periods when the machines are allowed to remain under natural draft. Much of the loss could no doubt be avoided with different operation during the heating period whereby the carbon might be burned in preference to heating-oil, for the reason that so long as this oil is present and products of combustion only come into contact with the carbon it will not burn. The heating-oil used is equivalent to 4,540,000 B.t.u. per cycle, while the carbon deposited in the machines and that expelled unburned amount to 6,360,000 B.t.u. per cycle.

Apparently there is sufficient carbon to eliminate the need of heating-oil altogether provided it can be burned in a way which will leave the heat from its combustion at the proper point in the machine.

Discussion of Length of Cycle

Concluding the discussion of losses and the possibility of reducing them, a study of the length of cycle may be profitable. Apparently the volume of water gas made during the purging period is very small, principally because of the lowered temperature existing in the generator at that time, and practically the only use of the steam purging is to displace the high B.t.u. gas derived from the oil. Experiments which we have made indicate that three or four minutes is a sufficient length of time to accomplish this, so that it appears that it should be possible to reduce the length of cycle from a total of thirty-six minutes to, say, thirty minutes, proportioned as follows:

Heating, seven or eight minutes.
Blasting, three or two minutes.
Making, sixteen minutes.
Purging, four minutes.

Such a change in cycle would reduce all continuing losses such as radiation and convection, steam for cooling sprays, etc., and would also cut down many other quantities involved. Some preliminary experiments indicate that this change is feasible but additional work is needed before arriving at a final decision. It may be possible that an even shorter cycle would be still better. The point is mentioned here merely to call attention to the possibilities along these lines.

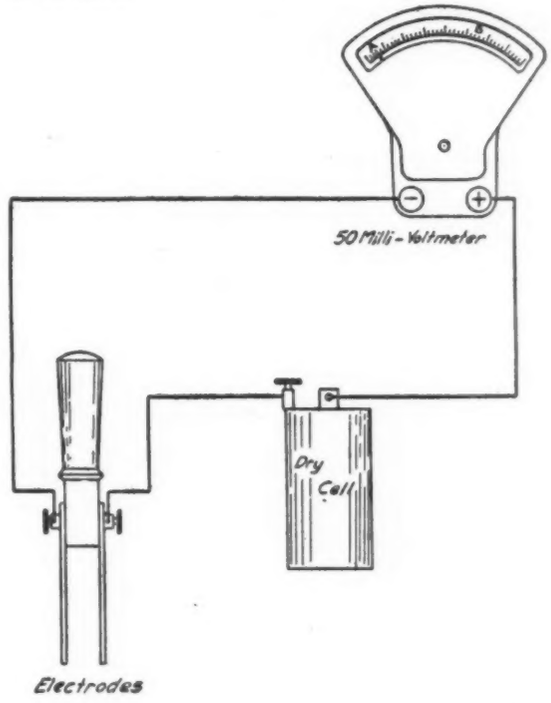


Fig. 8
DIAGRAM OF ELECTRICAL DETECTOR USED IN TAKING WATER VELOCITIES

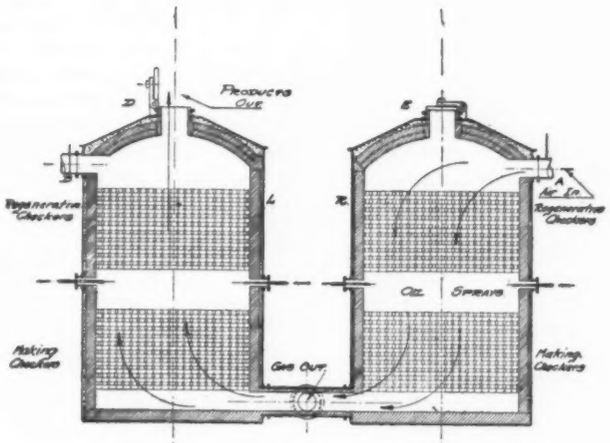


Fig No 9.
DIAGRAM OF TWIN GENERATOR SET
Illustrating Regenerative Principle of Preheating Blast Air.

Recapitulation of Possible Savings

If the various savings briefly indicated in the preceding sections as being possible could be realized in practice there would result gains in thermal efficiency as follows:

	Per Cent
Radiation and convection (0.66 of 1.38 per cent)	0.91
Stack gases (0.57 of 7.24 per cent)	4.85
Wash boxes (steam excess during make and purge, say 2,000,000 B.t.u. per cycle)	2.97
Heating oil (say 50 per cent replaced by burning carbon)	3.40
	12.13

This would raise the thermal efficiency to about 85 per cent, a figure better than that of the best steam-boiler practice.

Economic Aspects of Thermal Efficiency

Any discussion of thermal efficiency would not be complete without considering the relation between heat efficiency, per se, and economic efficiency. The two are by no means synonymous, since it is easily possible that the process could be so manipulated as to give a very high thermal efficiency and at the same time yield products of little or no economic value.

It is quite commonly a feature of industrial enterprise to find the profits to be derived from the greater commercial value of one or more of the products as compared with the others. It is thus quite possible and actually often happens that a sacrifice in thermal efficiency or total products recovery may result in larger profits or greater economic efficiency as evidenced by the production of a commodity for which there is a keenly felt need. It is the by-products which in many large enterprises have made the main operation possible and profitable.

In the case of oil-gas manufacture, the commercial values of the by-products of carbon, tar, and light oils should be most seriously considered in connection with the economic efficiency of the process.

Recently the term "fuel processing" has been

coined to describe the transformation of the raw materials into products having the greatest possible commercial and economic values. Our natural resources must be looked upon not merely as an essential ingredient of our own product but as a national asset to be worked up in a manner which will result in the greatest possible benefit to our economic life.

To conclude, even though it might be possible to produce our product—gas—from a minimum quantity of raw materials, that is to say, with the highest thermal efficiency, our industry might in spite of this fail to justify its prior right to these materials should there predominate a selfish or narrow viewpoint as a result of which we would fail to produce other useful products from the original materials. By this we mean such products as can be produced to the greatest economic advantage in connection with gas manufacture.

Table IV—Average Operating Data and Thermal Analysis Based on Special Tests and Works Records from July, 1920, to June, 1921, Inclusive

Portland Gas & Coke Company

A—General Items

1.	Average air temperature, deg. Fahr.	53.4
2.	Average barometric pressure —inches mercury	29.88
3.	Average number of machines kept heated	5.92
4.	Total number of runs made	67,094
5.	Total possible number of runs	86,340
6.	Actual runs per day	184
7.	Possible runs per day	237
8.	Average daily load factor	0.777
9.	Total send-out—cubic feet	3,365,000,000
10.	Average net make per run—cubic feet at 30 in. and 60 deg.	50,200
11.	Average net make per machine hour	83,700
12.	Average gas loss at works per change of purifiers	70,000
13.	Same, distributed over all runs —cubic feet per cycle	190
14.	Average gross make per run—cubic feet at 30 in. and 60 deg.	50,390

15. Average analysis of purified gas:

Constituent	Per Cent of Vol.	Per Cent by Wt.	Ultimate Analysis
CO_2	1.0	4.3	H = 23.6 per cent
C_6H_6	1.0	7.6	
C_2H_4	3.8	10.4	C = 55.0 per cent
O_2	0.1	0.3	
CO	6.8	18.6	O = 14.0 per cent
H_2	59.2	11.6	
CH_4	25.4	39.8	N = 7.4 per cent
N_2	2.7	7.4	

16.	Specific gravity of purified gas (air = 1)	0.3534
17.	Average heat value—B.t.u per cubic foot	570.6
18.	Average specific heat of gas (per pound from 32 to 1,800 deg. Fahr.)	0.8856
19.	Length of heating period—minutes	9
20.	Length of blasting period——minutes	3
21.	Length of making period—minutes	16
22.	Length of purging period—minutes	8
23.	Total length of cycle—minutes	36

B—Data on Products

24.	Average net weight of gas made—pounds per cycle	1,358
25.	Average heat in net gas made —B.t.u. per cycle	28,644,000
26.	Hydrogen sulphide removed —pounds per cycle	22
27.	Naphthalene removed—lb. per cycle	3
28.	Gross weight of gas (less tar and lampblack)—lb. per cycle	1,388
29.	Average weight of dry lampblack produced—lb. per M	23.2
30.	Average weight of dry lampblack produced—lb. per cycle	1,165
31.	Average heat value of lampblack—B.t.u. per pound	15,060
32.	Average heat in lampblack—B.t.u. per cycle	17,560,000
33.	Specific heat of lampblack	0.30
34.	Average (water-free) tar produced—lb. per cycle	126
35.	Average heat value of tar—B.t.u. per pound	16,425
36.	Average heat in tar—B.t.u. per cycle	2,070,000

37. Ultimate analyses:

	C	H	S
Lampblack	97	2.5	0.5%
Tar	91	9.0	...%

C—Making and Heating Oil Data

38.	Average making-oil per run—gallon	413.5
39.	Average making-oil per thousand—gallon	8.23
40.	Average gravity of oil—deg. B.	15.79
41.	Average moisture in oil—per cent	2.44
42.	Average weight per gal.—lb.	8.02
43.	Average making-oil per run—pound	3,320
44.	Average making-oil (water-free)—pounds per run	3,239
45.	Average heating value of oil—B.t.u. per pound	18,608
46.	Heat units in from making-oil —B.t.u. per cycle	60,250,000
47.	Average heating-oil per run—gallon	31.6
48.	Average heating-oil per thousand—gallon	0.63

49. Average heating-oil per run—pounds	253
50. Average heating-oil—lb. per run	247
51. Heat units in from heating-oil—B.t.u. per cycle	4,540,000
52. Moisture in making-oil—lb. per cycle	81
53. Moisture in heating-oil—lb. per cycle	6
54. Total oil—lb. per cycle	3,573
55. Average temperature of oil—deg. Fahr.	184.5
56. Specific heat of oil	0.498
57. Sensible heat in oil above 60 deg. Fahr.—B.t.u. per cycle	222,000
58. Steam used in oil heaters—lb. per cycle	237
59. Heat in steam above 60 deg. Fahr.—B.t.u. per pound	1,168
60. Heat units used in oil heaters—B.t.u. per cycle	276,000

D—Steam Data

61. Average total steam used—lb. per thousand	33
62. Steam used during heating period—pounds	357
63. Steam used during blasting period—pounds	222
64. Steam used during making period—pounds	893
65. Steam used during purging period—pounds	188
66. Average total steam used—lb. per cycle	1,660
67. Heat content in steam used—B.t.u. per lb. above 600 deg. Fahr.	1,168
68. Heat in steam used—B.t.u. per cycle	1,940,000

E—Blast-Air and Stack-Gas Data

69. Average air used for blast—cubic feet per cycle	141,500
70. Average weight of dry air used—lb. per cubic foot	0.0779
71. Average weight of dry air used—lb. per cycle	11,020
72. Average temperature of blast air—deg. Fahr.	79
73. Specific heat of air	0.2374
74. Heat content above 60 deg. Fahr. of blast air—B.t.u. per cycle	49,800
75. Moisture in blast air—lb. per cycle	99
76. Water from steam during heating—lb. per cycle	579
77. Steam condensed in wash box during heat—lb. per cycle (Item 113 ÷ item 130)	320
78. Steam from combustion of heating-oil—lb. per cycle	245
79. Average total water in stack—lb. per cycle (Item 75 + 76 + 78 — 77)	603
80. Average temperature of stack gases—deg. Fahr.	1,434
81. Heat content above 60 deg. Fahr. of moisture in stack gases—B.t.u. per cycle	1,880
82. Average weight of dry stack gas products—lb. per cycle	11,059
83. Average specific heat of dry-stack gases	0.24
84. Heat lost in dry-stack gases—B.t.u. per cycle	3,655,000
85. Heat content in steam in stack gases—B.t.u. per lb. above 60 deg. Fahr.	1,733
86. Heat lost in steam in stack gases—B.t.u. per cycle	1,047,000
87. Heat lost in CO in stack gases—B.t.u. per cycle (36 lb. × 4,369)	157,500
88. Total heat lost in stack gases—B.t.u. per cycle (Note—Items 82 to 87 are calculated from stack-gas data shown in figure 5.)	4,859,500

F—Radiation and Convection

89. Area of generator shell and hot projections—square feet	2,747
90. Average temperature of generator shells—deg. Fahr.	247
91. Average air temperature in generator house—deg. Fahr.	75
92. Average heat-loss constant—B.t.u. per sq. ft. per deg. difference	3.29
93. Radiation and convection loss—B.t.u. per cycle	926,300

G—Wash-Box Loss from Cooling of Gas, Etc.

94. Weight of raw gas (less tar and lampblack)—lb. per cycle	1,388
95. Average temperature of gas leaving machine—deg. Fahr.	1,710
96. Sensible heat of gas leaving—B.t.u. per cycle above 60 deg. Fahr.	2,025,000
97. Sensible heat of lampblack leaving—B.t.u. per cycle above 60 deg. Fahr.	576,500
98. Sensible heat of tar leaving—B.t.u. per cycle above 60 deg. Fahr.	104,000
99. Specific heat taken for tar	0.50
100. Average temperature of gas leaving wash box—deg. Fahr.	138
101. Sensible heat in gas from wash box—B.t.u. per cycle above 60 deg. Fahr.	93,700
102. Heat lost by gas in wash box B.t.u. per cycle	1,931,300
103. Heat lost by gas, tar, and lampblack in wash box—B.t.u. per cycle	2,611,800

H—Wash-Box Loss from Condensing of Steam

104. Average temperature of water entering wash box—deg. Fahr.	79
105. Average temperature of water leaving during make—deg. Fahr.	141
106. Water passing through wash box during make—pounds	66,000
107. Heat carried away during make—B.t.u.	4,090,000
108. Average temperature of water during purge—deg. Fahr.	138
109. Water passing through during purge—pounds	12,600
110. Heat carried away during purge—B.t.u.	744,000
111. Average temperature of water during heat—deg. Fahr.	118
112. Water passing through during heat—pounds	15,120
113. Heat carried away during heat—B.t.u.	590,000
114. Total heat carried away by water—B.t.u. per cycle	5,424,000

I—Water Gas Made

115. Water gas made in process—cubic feet per cycle 5,000
(Determined from a number of steam runs at average operating temperature. Volume assumed to be the same with making-oil in; this may or may not be entirely correct. The true volume is very probably less than that given.)

116. Analysis of water gas:

	% by Volume	% by Weight	Ultimate Analysis
CO_2	18.4	51.5	
O_2	0.0	0.0	
CO	19.6	34.9	C 30.9%
H_2	57.4	7.3	O 57.4%
CH_4	2.5	2.5	H 7.9%
N_2	2.1	3.8	N 3.8%

117. Specific gravity of water gas made	0.542
118. Weight of water gas made—lb. per cycle	208
119. Heat value of this gas—B.t.u. per cu. ft. at 30 in. 60 deg.	276
120. Hydrogen in this gas—lb. per cycle	16.4
121. Equivalent steam weight required—lb. per cycle	147

J—Steam Condensed in Wash Box

122. Total steam (item 66)—lb. per cycle	1,660
123. Water in oil (item 52 + item 53)—lb. per cycle	87
124. Moisture in blast air (item 75)—lb. per cycle	99
125. Water to which hydrogen in heating-oil burns—lb. per cycle	245
126. Total water into generator—lb. per cycle	2,091
127. Steam out with stack gases—lb. per cycle	603
128. Steam not condensed in wash box (item 127 + item 121)	750
129. Steam condensed in wash box (item 126 — item 129)	1,341
130. Heat content of steam condensed—B.t.u. per lb. above 60 deg. Fahr.	1,842
131. Heat given up by steam to wash water—B.t.u. per cycle	2,475,000
132. Total heat lost in wash box—B.t.u. per cycle	5,086,800

K—Heat Interchanges in Purifying Process, Etc.

133. Average heat of gas above 60 deg. Fahr. at scrubber outlet—B.t.u. per cycle	49,900
135. Sensible heat lost by gas in scrubber—B.t.u. per cycle	43,800
136. Average temperature of gas at relief holder outlet—deg. Fahr.	83.8
137. Sensible heat of gas at relief holder outlet—B.t.u. per cycle	29,200
138. Sensible heat lost by gas relief holder—B.t.u. per cycle	14,600
139. Average temperature of gas at oil scrubber outlet—deg. Fahr.	80.3
140. Sensible heat of gas at oil scrubber outlet—B.t.u. per cycle	25,500
141. Sensible heat lost by gas in oil scrubber—B.t.u. per cycle	3,700
142. Average temperature of gas leaving exhausters—deg. Fahr.	91.9
143. Sensible heat of gas at exhauster outlet—B.t.u. per cycle	39,100
144. Sensible heat gained by gas in exhauster—B.t.u. per cycle	13,500
145. Average temperature of gas leaving naphthaline washer—deg. Fahr.	86.7
146. Sensible heat in gas leaving naphthaline washer — B.t.u. per cycle	32,700
147. Sensible heat lost by gas in naphthaline washer — B.t.u. per cycle	6,400
148. Average naphthalene in gas at scrubber inlet—gr. per 100 cu. ft.	35
149. Average naphthalene in gas at scrubber inlet—lb. per cycle	2.51
150. Average naphthalene in purified gas—gr. per 100 cu. ft.	15
151 Average naphthalene in purified gas—lb. per cycle	1.07

152.	Average naphthalene removed—lb. per cycle	1.44
153.	Heat value of naphthalene removed	25,100
154.	Average temperature of gas leaving purifiers—deg. Fahr.	71.2
155.	Sensible heat in gas leaving purifiers above 60 deg. B.t.u. per cycle	13,400
156.	Sensible heat lost by gas in purifiers—B.t.u. per cycle	19,300
157.	Plant losses—changing purifiers, etc.—cu. ft. per cycle	190
158.	Heat equivalent of plant losses—B.t.u. per cycle	10,800
159.	Average H_2S absorbed by purifiers—lb per cycle	22
160.	Heat value of H_2S absorbed—B.t.u. per cycle	164,000
161.	Average temperature of gas leaving station meters	70.4
162.	Average temperature of gas leaving works holder—deg. Fahr.	65
163.	Sensible heat of gas above 60 deg. at holder outlet—B.t.u. per cycle	6,000
164.	Sensible heat lost in meters, holder, etc.—B.t.u. per cycle	7,400

L—Determination of Carbon Deposited in Machines and Leaving as Unburned Fuel with Stack Gases

165. Ultimate analysis of oil (average)

C = 87% H = 11%
S = 1% N = 0.75%
O = 0.25%

166.	Total carbon into machine (3,486 × 0.87)—lb. per cycle	3,032
167.	Carbon out in gas—lb. per cycle	749
168.	Carbon out in lampblack—lb. per cycle	1,130
169.	Carbon out in tar—lb. per cycle	115
170.	Carbon out in naphthalene—lb. per cycle	3
171.	Carbon out in CO_2 in stack gases—lb. per cycle	583
172.	Carbon out in CO in stack gases—lb. per cycle	15
173.	Total carbon out—lb. per cycle	2,595
175.	Heat value of carbon—B.t.u. per lb.	14,544
176.	Heat in carbon deposited and unburned—B.t.u. per cycle	6,360,000

M—Heat Lost at End of Make

177.	Free volume of machine—cu. ft.	4,550
178.	Volume of gas reduced to 30 in. and 60 deg.—cu. ft.	1,190
179.	Heat value of gas at end of purge—B.t.u. per cycle	276
180.	Heat lost due to opening of machine—B.t.u. per cycle	329,000

Summary

1. A study of the thermal efficiency and complete heat balance of an oil gas set is presented. This is based on operating records and special tests made at the works of the Portland Gas & Coke Company.

2. The over-all thermal efficiency is found to be 72.07 per cent.

3. Individual losses are segregated and analyzed. The largest of these losses in order of magnitude are found to be the following: Heat in carbon deposited and unburned, 9.48 per cent; heat lost in wash box, 7.59 per cent; heat lost in stack gases, 7.24 per cent; heat lost in radiation and convection, 1.38 per cent.

4. Special methods used for measuring shell temperature, radiation and convection, and flow of water are described in detail.

5. Possibilities for the reduction or utilization of heat lost are discussed. This includes a consideration of waste heat boilers, regenerative heating of blast air, reduction of steam used, more perfect heat insulation, and certain changes in operation and length of cycle. The total possible saving is estimated at 12.13 per cent, making the possible thermal efficiency 84.20 per cent, or better than that of the best steam boiler practice.

6. Various aspects of thermal vs economic efficiency are discussed and it is pointed out that the two are not necessarily the same.

7. The necessity of a more careful study of by-products possibilities is urged.

Old-Age Meter Changes

(*Continued from page 324.*)

ing the truth of such a condition and he is able to recommend a selective method of meter changes, there is no question in the author's mind but that the various regulatory bodies will willingly amend their rulings accordingly.

It is the author's belief that much of the remedy will be found in prevention rather than cure, and that the life of meters in service can be greatly prolonged by proper attention to the various conditions under which they must operate.

The location of a gas meter with respect to its susceptibility to mechanical injury, temperature variations, condensation, etc., has a varying effect upon the operation, registration and length of its useful service. For the purpose of substantiating this contention, 807 meter locations were inspected and a record made of the conditions under which each meter was operating. The meters were then immediately removed and tested, and as a result the recapitulation will be found on page 336.

It will be noted that where meters were subjected to temperature variations it was found that they ran fast. The meters listed under the heading "Temperature Variations" were invariably subjected to heat above normal, in that they were located in basements near a furnace; while, on the other hand, those located on the outside of the building were subjected to the sun's rays, the prevailing temperatures below normal not being of sufficient duration to offset the higher temperatures experienced.

TABLE NO. 4

Effect of a Meter's Location Upon Its Accuracy

	Water in Meter		Liability to Temp. Variation		Naphthalene in	Meters Injured		Location	
	Basement	Outside	Basement	Outside	Service	Basement	Outside	Basement	O'side
Total number	24	5	22	51	6	110	41	716	91
Number O. K.	7	....	4	6	....	18	2	94	12
Number fast	8	2	11	27	4	72	14	335	47
Number slow	8	3	7	16	2	32	12	273	31
Number D. R.	....	....	....	....	....	....	....	6	....
Number stuck	1	....	....	2	....	....	....	8	1
Per cent of total O. K.	29.10	....	18.20	11.70	....	18.30	4.90	13.10	13.20
Per cent of total fast	33.30	40.00	45.50	52.80	66.60	63.50	34.10	46.80	51.60
Per cent of total slow	33.30	60.00	31.90	31.40	33.30	29.10	29.30	36.20	34.10
Per cent of total D. R.	....	....	....	....	....	....	....	0.80	....
Per cent of total stuck	4.20	....	....	3.90	....	....	....	1.10	1.10
Per cent plus or minus	—1.30	—1.00	+0.59	+0.52	+0.50	+0.35	+0.83	—0.96	+0.56

We will arbitrarily assume that the life of a gas meter is largely contingent upon the life of its diaphragm, and that the conditions under which it operates materially lengthen or shorten the life of the diaphragm.

Before attacking the enemies of the diaphragm, it was thought advisable to establish, if possible, the average life of a meter diaphragm under the conditions under which it was called upon to operate with the Portland Gas & Coke Company. We therefore examined 60,000 meter-repair cards and found that the last 500 diaphragm replacements were made after an average service of ten and one-quarter years, as set forth in Table No. 5.

TABLE NO. 5

Size of Meter	No. of Meters	Total No. Yrs. Service	Average No. Yrs. Service
3	52	319.19	7.52
5	409	4,351.25	10.64
10	10	109.34	10.93
30	9	100.03	11.11
45	5	56.98	11.39
60	5	52.66	10.53
100	9	57.24	6.36
200	1	10.67	10.67
Totals	500	5,129.36	10.25

The gas company, by necessity, must depend upon the records of the meter-proving room, and, for the purpose of verifying that meters tested on consumers' premises would give the same test after removal to proving room, thirty-two meters were carefully tested under the supervision of an engineer, on the premises of the consumers, by means of a portable test meter. These meters were then immediately removed and transported in the regular manner to the meter-proving room, after which they were tested according to the ordinary routine. The findings are set forth in Table No. 6.

SUMMARY OF DATA COVERED IN TABLE NO. 6

	Field	Shop
Number tested fast	14	13
Average per cent fast	2.9	2.3
Number tested slow	9	10
Average per cent slow	51.2	49.2
Number D. R	9	9
Total number tested	32	32
(1) Net inaccuracy in field		30.1%
(2) Net inaccuracy in shop		30.4%
Total difference		0.3%

The meters considered in the foregoing tabulation were removed on orders originating from special cases, and are not representative of general conditions but do illustrate the specific points in question.

It must be considered that temperature conditions in the field were not ideal, and no corrections were made in this respect and a slight allowance should be made. To all intents and purposes the tests in the field confirm the proving-room tests.

However, if we must continue to operate under certain arbitrary periods for meter removals it becomes interesting to compute the economical point resulting from a minimum loss in operating revenue chargeable to improper registration as compared with the cost of periodical meter changes.

For the purpose of this calculation we shall use the operating costs of the Portland Gas & Coke Company.

There are three factors which constitute the major items from a gas company standpoint in connection with this traffic which must be considered separately:

Frequency of periodical changes and cost thereof.
Frequency of repairs and cost thereof.
Loss through improper registration.

Cost of Changing

The principal item of expense in the cost of changing meters is readily conceded to be labor. It is thought, therefore, that more money can be saved in connection with this performance through routing than in any other way. The efficiency of a meter changes may be readily decreased or increased 25 per cent by the mere fact that he is properly or improperly routed.

The next item of importance in connection with the changing of meters is that of cartage. The horse and wagon is still conceded to be the cheapest in downtown and strictly close-in districts. In apartment-house districts, where a relatively large number of meters are located, a wholesale delivery of meters is the most advantageous, in which the fitter is dispatched on foot or on street car and remains in that district until work of that character is finished, his meters and supplies being sent to him daily as the work advances.

The Portland Gas & Coke Company has for the past two years used a fleet of motorcycle side cars, in connection with old-age changes, to very good advantage.

Cost of Repairs

The economical repair of meters is probably accomplished more through organization and ample equip-

ment than by all other items combined. The workmen, by necessity, are continually under the eye of the foremen, and inefficient workmen find the meter shop a poor harbor. For this reason I repeat that an efficient meter shop reflects almost at once the character of management.

The meter shop also readily lends itself to a bonus system of compensation for the workmen, and it is recommended that any who are not employing the bonus system should, where circumstances permit, give this idea a trial.

Further economy will be attained through the standardization of meters; that is to say, additions to plant account should be of one given make, as near as possible. The old saying that "Practice makes perfect" surely holds good in connection with the meter shop when the workmen become familiar and are called upon to handle a larger number of the same type of meters. The standardization of meters not only facilitates the work in the meter shop but greatly simplifies the buying and stocking of repair parts, together with the changing and setting of meters in the field.

Loss Through Improper Registration

For the purpose of this computation we will assume that meters are being charged at the expiration of an arbitrary period. We will assume that such inaccuracy increases at the rate of 0.5 per cent per annum; hence we have the following tabulation of inaccuracy and corresponding loss in revenue:

TABLE NO. 7

Loss per Annuma per Customer Based on Average Monthly Gas Bill of 3.265 Cu. Ft.

No. Years	% Accuracy	Accumulative Yearly Loss (in Cu. Ft.)	Accumulative Yearly Loss (in dollars)
1	0.5	196	$0.26
2	1.0	391	0.52
3	1.5	587	0.78
4	2.0	783	1.04
5	2.5	978	1.30
6	3.0	1,174	1.56
7	3.5	1,570	1.62
8	4.0	1,563	2.08
9	4.5	1,761	2.34
10	5.0	1,957	2.60

From Table No. 7 it now becomes possible to draw up a tabulation showing the yearly cost incurred by leaving the meter in service under the preceding conditions, which tabulation is given:

TABLE NO. 8

Yrs. in Service	Accum. Loss in Revenue Due to Inaccuracy	Cost of Repairs	Cost of Changes	Total Accum. Cost	Aver. Annual Cost
1	$0.26	$1.85	$1.46	$3.57	$3.57
2	0.52	1.65	1.46	3.83	1.91
3	0.78	1.85	1.46	4.09	1.36

TABLE NO. 6

Field and Shop Tests of Maryland Meters

No. and Location of Meter	Liability to Temp. Variation	Water in Meter	Is Meter Level	Is Meter Near Wood Pile	Field Test % Fast	Field Test % Slow	Field Test D.R.	Prover Test % Fast	Prover Test % Slow	Prover Test D.R.
534—Basement	No	No	Yes	No	1.00	....	....	....	6.50	....
4563—Basement	No	No	Yes	No	2.50	....	....	2.00	....	....
5627—Basement	No	No	Yes	No	....	....	....	....	4.00	....
11662—Under house	Yes	No	Yes	No	....	1.50	....	....	1.50	....
14727—Basement	Yes	No	Yes	No	2.50	....	....	5.50	....	....
15137—Under house	No	No	Yes	No	....	....	D.R.	....	....	D.R.
15532—Basement	No	Yes	Yes	Yes	10.00	....	....	....	10.00	....
16011—Basement	No	No	Yes	No	....	....	D.R.	....	....	D.R.
16525—Inside	No	Yes	Yes	No	....	....	D.R.	....	....	D.R.
18342—Basement	No	No	Yes	No	0.25	....	....	+	....	....
20230—Basement	No	Yes	Yes	No	....	....	D.R.	....	....	D.R.
22001—Basement	No	No	Yes	Yes	....	....	D.R.	....	....	D.R.
22318—Basement	No	No	Yes	No	....	....	D.R.	....	....	D.R.
23052—Hall	No	No	Yes	No	3.50	....	....	2.00	....	....
24393—Hall	No	No	Yes	No	+	....	....	+	....	....
24800—Basement	No	No	Yes	No	....	....	D.R.	....	....	D.R.
25649—Living room	Yes	No	No	No	....	....	D.R.	....	....	D.R.
27214—Inside	Yes	No	Yes	No	10.00	....	....	8.50	....	....
31205—Basement	No	No	No	No	7.00	....	....	4.00	....	....
37676—Basement	No	No	No	No	....	....	D.R.	....	....	D.R.
38131—Basement	No	No	No	No	1.25	....	....	1.00	....	....
39257—Shop	No	No	Yes	No	....	3.50	....	....	3.50	....
40933—Under house	No	No	Yes	No	3.25	....	....	3.00	....	....
43828—Basement	No	No	Yes	No	....	3.50	....	....	2.00	....
58007—Basement	No	No	Yes	No	2.25	....	....	1.00	....	....
62126—Basement	No	No	No	No	2.50	....	....	1.00	....	....
63786—Basement	No	No	Yes	No	....	1.50	....	....	3.00	....
64669—Porch	No	No	Yes	No	1.50	....	....	1.00	....	....
78104—Basement	Yes	No	Yes	No	....	2.00	....	....	2.00	....
78724—Basement	No	No	Yes	No	....	1.00	....	....	1.00	....
83265—Under house	No	No	Yes	No	....	1.00	....	....	1.50	....
84918—Basement	No	No	Yes	No	1.00	....	....	1.00	....	....
Total					14.00	9.00	9.00	13.00	10.00	9.00

4.....	1.04	1.85	1.46	4.35	1.00
5.....	1.30	1.85	1.46	4.61	0.92
6.....	1.56	1.85	1.46	4.87	0.81
7.....	1.82	1.85	1.46	5.13	0.73
8.....	2.08	1.85	1.46	5.39	0.67
9.....	2.34	1.85	1.46	5.65	0.63
10.....	2.60	1.85	1.46	5.91	0.59

From this tabulation and chart it is seen, under the assumed conditions, that the minimum combined loss in revenue and operating expense occurs with meter changes after the tenth year.

A similar calculation can be made for any particular local condition.

It must be remembered, however, that the minimum loss from an operating standpoint in connection with this tabulation will vary from year to year, depending on the fluctuation in the cost of labor and material. Consider, therefore, that the cost of labor and material listed in the foregoing is now at its peak. In the event that the labor and material decline in cost, then the lower cost of meter changes and repairs would materially decrease the length of time a meter could be left in service; while, on the other hand, the calculation is affected by a change in the rates for gas.

Since we have established ten and one-quarter years as being the average life of diaphragms removed from at least 500 meters, then we may reasonably assume that the maximum period of continuous service for a gas meter should not exceed ten years.

An analysis of the Portland Gas & Coke Company's meter records as set out in the foregoing plainly shows that it is not necessary to change meters every five years in order to insure either the customer or the company against undue loss.

It is definitely shown that the inaccuracies of our meters do not warrant changing on account of old age within a period of less than ten years. How much longer a meter could reasonably remain in service our statistics do not clearly divulge, due principally to the fact that a sufficient number of meters were not available for test that had seen continual service in excess of ten years.

Our findings do prove that it is an expensive policy to remove meters at the end of five years. Our findings do indicate that we should have an opportunity to give the question of old-age meter change further consideration and investigation by leaving meters in service for a period of years sufficient to enable us to establish a danger point.

Our computations do show the fact that it costs $4.61 to maintain a meter in service for five years, or an average of 92 cents per year, which sum of money includes the loss through inaccuracy, cost of changes and repairs; whereas, if the same meter were allowed to continue in service for at least ten years our total expense from the same source would amount to $5.91, or an average of 59 cents per year. It is evident, therefore, that a saving of 33 cents per meter per year is accomplished on a ten-year change program.

The Portland Gas & Coke Company has 75,000 meters in use, and 15,000 meters are changed yearly for old-age reasons on the five-year policy. Our operating expense and loss through registration on 15,000 meters at $4.61 per meter would amount to a yearly sum of $69,150.

On the other hand, if meters were allowed to remain in service for ten years our average yearly expense would equal $44,325, or a saving of 33 cents per meter, or $24,825 per year, in favor of the ten-year program.

It is a point easily conceded that money should be spent judiciously. The facts brought out here do not indicate that a five-year old-age meter change policy represents judicial expenditure. It is the opinion of the author that, if necessary, a more liberal use of complaint-recording meters, a more liberal use of high-bill inspectors, coupled with more attention by bookkeepers to consumers' accounts, would, as compared with the expense incurred in connection with old-age meter changes, save more money for the company and be more beneficial to the consumer.

Summary

1. The tabulations and supporting information lead us to believe that the findings of the modern meter proving room are representative of conditions on consumers' premises.
2. That the average life of diaphragms is not materially affected on account of the location of a meter, that is set in keeping with the modern interpretation of good practice, and not subjected to high temperatures.
3. A tabulation of 27,484 meters removed from service of the Portland Gas & Coke Company shows no definite relationship between accuracy of registration and length of period in service.
4. A logical deduction would be that meters should be changed for cause rather than arbitrarily.
5. The correct registration of meters is preferably attained by controlling the conditions under which they operate rather than by frequent removals from service.
6. Given the cost of repairing meters, changing meters and having assumed further that a progressive inaccuracy exists, it is possible by mathematical computation to indicate for these particular conditions the period of time during which a meter may be allowed to remain in service.
7. That the length of continuous service of a meter is contingent upon the life of its diaphragm.

Gives Reason for Sulphur Content

At the Central District Experiment Station at Urbana, Ill., an examination of samples collected in the Pratt coal seam in Alabama shows that the variation of sulphur content is due almost entirely to variations in the amounts of pyritic sulphur, the organic sulphur content remaining constant. The determination of sulphur in raw coal and washed coal collected at the washery of the Woodward (Ala.) Iron Company confirms previous conclusions that organic sulphur cannot be removed by washing and is often higher in the washed coal.